RESULTS OF THE SECOND U.S. MANNED SUBORBITAL SPACE FLIGHT JULY 21, 1961

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FOREWORD

This document presents the results of the second United States manned suborbital space flight. The data and flight description presented form a continuation of the information provided at an open conference held under the auspices of the National Aeronautics and Space Administration, in cooperation with the National Institutes of Health and the National Academy of Sciences, at the U.S. Department of State Auditorium on June 6, 1961. The papers presented herein generally parallel the presentations of the first report and were prepared by the personnel of the NASA Manned Spacecraft Center in collaboration with personnel from other government agencies, participating industry, and universities.

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1. INTRODUCTION

By Robert R. Gilruth, *Director, NASA Manned Spacecraft Center*

The second successful manned suborbital space flight on July 21, 1961, in which Astronaut Virgil I. Grissom was the pilot was another step in the progressive research, development, and training program leading to the study of man's capabilities in a space environment during manned orbital flight. Data and operational experiences gained from this flight were in agreement with and supplemented the knowledge obtained from the first suborbital flight of May 5, 1961, piloted by Astronaut Alan B. Shepard, Jr.

The two recent manned suborbital flights, coupled with the unmanned research and development flights, have provided valuable engineering and scientific data on which the program can progress. The successful active participation of the pilots, in much the same way as in the development and testing of high performance aircraft, has greatly increased our confidence in giving man a significant role in future space flight activities.

It is the purpose of this report to continue the practice of providing data to the scientific community interested in activities of this nature. Brief descriptions are presented of the Project Mercury spacecraft and flight plan. Papers are provided which parallel the presentations of data published for the first suborbital space flight. Additional information is given relating to the operational aspects of the medical support activities for the two manned suborbital space flights.

2. SPACECRAFT AND FLIGHT PLAN FOR THE MERCURY-REDSTONE 4 FLIGHT

By Jerome B. Hammack, *Mercury-Redstone Project Engineer, NASA Manned Spacecraft Center*

Introduction

The Mercury spacecraft is described in some detail in references 1 and 2. The MR–4 flight was the fourth mission in the Mercury-Redstone series of flight tests, all of which utilized the Mercury spacecraft. Each spacecraft differed in small details, and the differences between the MR–3 and the MR–4 spacecraft are discussed herein.

As shown in figure 2–1, the main configuration differences were the addition to the MR–4 spacecraft of a large viewing window and an explosively actuated side hatch.

Window

The addition of the large viewing window in the position shown in the figure was a result of a change requested by the Mercury astronauts. This window enables the astronaut to have a greater viewing area than the original side port windows. The field of view of the window is 30° in the horizontal plane and 33° in the vertical.

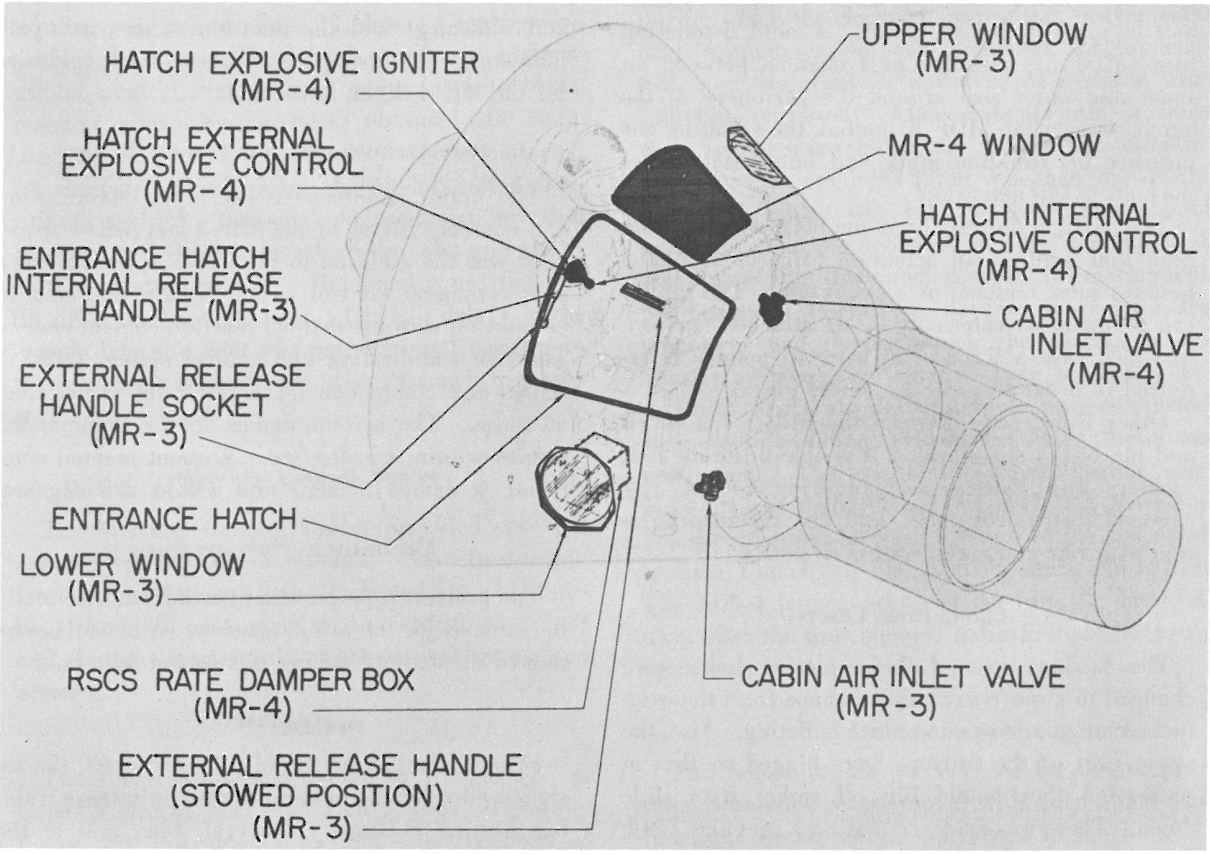

Figure 2–1. Configuration differences between MR–3 and MR–4 spacecraft.

The window is composed of an outer panel of 0.35-inch-thick Vycor glass and a 3-layer inner panel. The top layer of this inner panel is 0.17-inch-thick Vycor glass and the other two layers are 0.34-inch-thick tempered glass. The Vycor glass panels will withstand temperatures in the range of 1,500° to 1,800° F. The inner layers of tempered glass will withstand the cabin-pressure differences. Magnesium fluoride coatings were applied to reduce glare. Although not installed for the MR–4 flight, a removable polaroid filter to reduce glare further and a red filter for night adaption are available for the window.

Side Hatch

The explosively actuated side hatch was used for the first time on the MR–4 flight. The mechanically operated side hatch on the MR–3 spacecraft was in the same location and of the same size, but was considerably heavier (69 pounds as installed rather than 23 pounds).

The explosively actuated hatch utilizes an explosive charge to fracture the attaching bolts and thus separate the hatch from the spacecraft. Seventy ¼-inch titanium bolts secure the hatch to the doorsill. A 0.06-inch-diameter hole is drilled in each bolt to provide a weak point. A mild detonating fuse (MDF) is installed in a channel between an inner and outer seal around the periphery of the hatch. When the MDF is ignited, the resulting gas pressure between the inner and outer seal causes the bolts to fail in tension.

The MDF is ignited by a manually operated igniter that requires an actuation force of around 5 pounds, after removal of a safety pin. The igniter can be operated externally by an attached lanyard, in which case a force of at least 40 pounds is required in order to shear the safety pin.

Other differences between the MR–3 spacecraft and the MR–4 spacecraft, not visible in figure 2–1, include: (a) redesigned clamp-ring covers, (b) changed instrument panel, and (c) the incorporation of a rate command control system.

Clamp-Ring Covers

The fairings around the explosive bolts were changed to a more streamlined shape from the original rectangular shape to reduce buffeting. Also, the upper part of the fairings were hinged so that at separation they would flip off rather than slide down. There was evidence that on a previous Little Joe-Mercury flight, the umbilical connections had

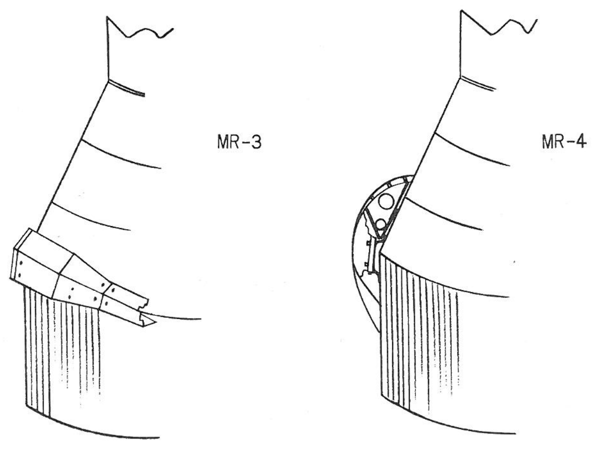

FIGURE 2–2. Clamp-ring covers for MR–3 and MR–4 spacecraft.

been damaged by this sliding action. Figure 2–2 shows the differences between the MR–3 and MR–4 covers.

Instrument Panel

A comparison between the MR–4 spacecraft instrument panel, shown in figure 2–3, and the MR–3 panel, presented in reference 1, reveals that the differences were mainly the rearrangement of controls and indicators and the addition of an earth-path indicator. The earth-path indicator was inoperative for the MR–4 flight, however.

Rate Stabilization and Control System

The major difference between the stabilization and control systems of the MR–3 and MR–4 spacecraft was the addition to the MR–4 spacecraft of a rate command control system which operated in connection with the manual reaction control system. The rate stabilization and control system (RSCS) senses and commands spacecraft rates rather than attitudes. The system damps to the commanded rate to within ±3 deg/sec. Without manual command, it damps to zero rate within ±3 deg/sec.

Prelaunch Preparations

The prelaunch preparation period was essentially the same as for the MR–3 mission. A brief description of the activity during this period follows.

Astronaut

Prior to launch of the MR–4 spacecraft, the assigned pilot for the mission started an intense training routine at Cape Canaveral, Fla., and at the NASA Manned Spacecraft Center, Langley Air

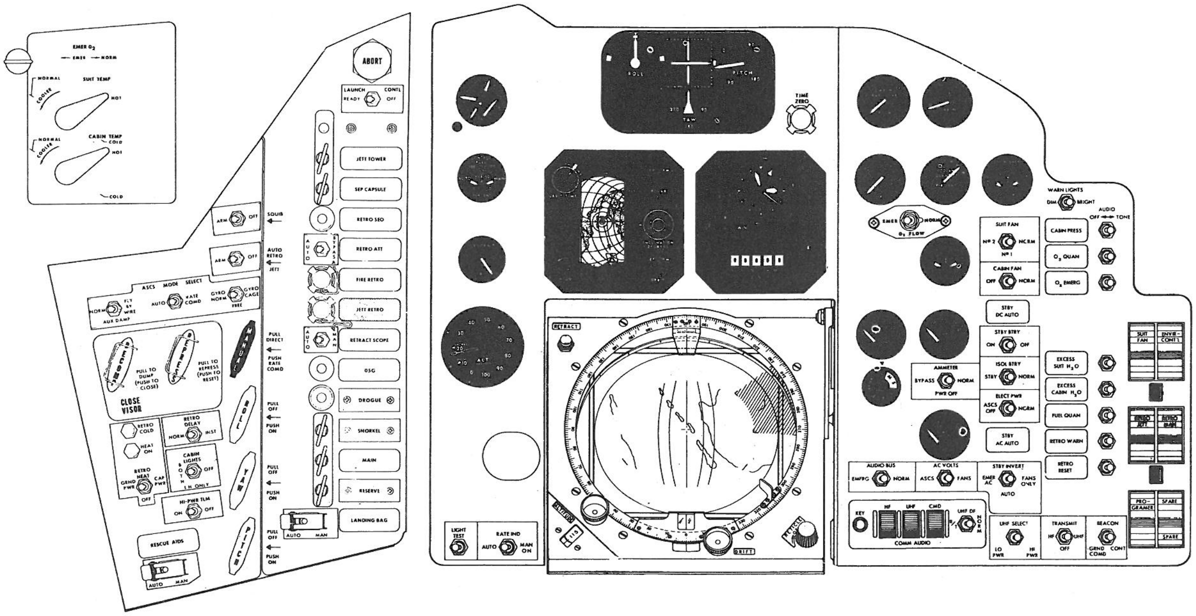

FIGURE 2–3. Main instrument panel and consoles for MR–4 spacecraft.

Force Base, Va., to familiarize himself with the various details of the spacecraft systems and to sharpen his reactions to various situations. During this period, the pilot participated in a centrifuge training program in which 17 Mercury acceleration profiles were run. The pilot took part in environmental control system tests, communication tests, reaction control system tests; obtained 100 simulated missions on the procedures trainer; conducted 36 simulated missions on the air-lubricated free-attitude (ALFA) trainer; and practiced insertion exercises and RF tests in which the pilot and spacecraft were exercised in a simulated count through lift off. On July 21, 1961, after two delays in the launch date, the pilot was prepared and inserted in the spacecraft at 3:58 a.m. e.s.t. Launch occurred at 7:20 a.m. e.s.t.

Mercury Control Center

The Mercury Control Center provided excellent support for the MR–4 mission. Numerous simulated flights were run prior to launching which utilized the flight astronauts in the procedures trainer and the personnel of the flight control center and network.

Spacecraft

The spacecraft was delivered to Hangar "S" at Cape Canaveral, Fla., on March 7, 1961. Upon delivery, the instrumentation and selected items of the communication system were removed from the spacecraft for bench testing. After reinstallation of the components, the systems tests proceeded as scheduled with only slight interruptions for work periods. Those tests required a total of 33 days, during which the electrical, sequential, instrumentation, communication, environmental, reaction-control, and stabilization and control systems were individually tested. After systems tests, a short work period was required to install the landing-impact bag. A simulated flight was then run on the spacecraft which was followed by installation of parachutes and pyrotechnics, weighed and balanced, and delivered to the launch complex for mating with the booster. Twenty-one days were spent on the launching pad during which the spacecraft and booster systems were checked both separately and as a unit. After the systems checks were completed, a spacecraft—launch-vehicle simulated flight was performed. The spacecraft—launch-vehicle combination was then ready for launch. A period of 136 days elapsed between delivery of the spacecraft to Cape Canaveral, Fla., and its successful launch. The MR–4 launch occurred on July 21, 1961, 47 days after the first manned ballistic flight by Astronaut Alan B. Shepard, Jr.

Launch Vehicle

The launch-vehicle system checks and preparations proceeded as scheduled with only minor malfunctions which caused no delays in the schedule. During the split countdown on the launching pad,

the launch-vehicle countdown proceeded smoothly with no hold periods chargeable to the launch-vehicle systems.

Countdown

The MR–4 spacecraft was launched at 7:20 a.m. e.s.t. on July 21, 1961 (fig. 2–4). The launch was originally scheduled for July 18, 1961, but was rescheduled to July 19, 1961, because of unfavorable weather conditions. The launch attempt of July 19,

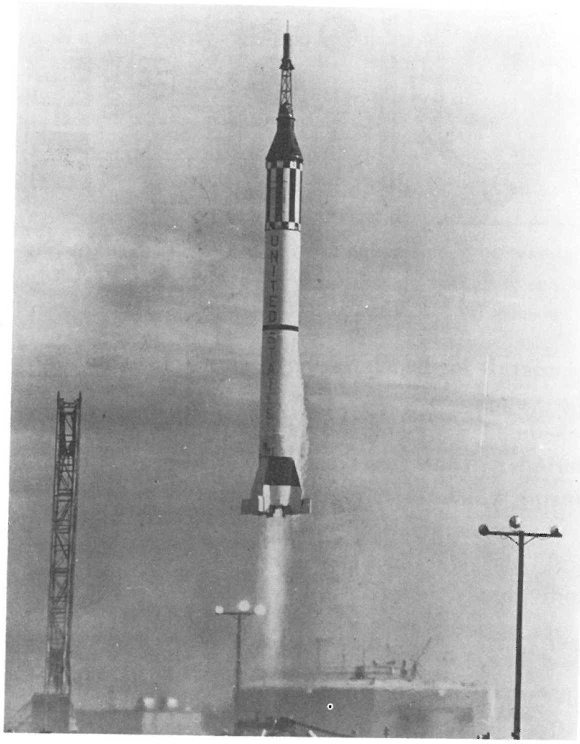

FIGURE 2–4. Launch of the Mercury-Redstone 4 from Cape Canaveral launch site on July 21, 1961.

1961, was canceled at T−10 minutes as a result of continued unfavorable weather. The launch was then rescheduled for July 21, 1961. The first half of the split launch countdown was begun at 6:00 a.m. e.s.t. on July 20, 1961, at T−640 minutes. Spacecraft preparation proceeded normally through the 12-hour planned hold period for hydrogen peroxide and pyrotechnic servicing. Evaluation of the weather at this time affirmed favorable launch conditions. The second half of the countdown was therefore begun at 2:30 a.m. e.s.t. on July 20, 1961. At T−180 minutes, prior to adding liquid oxygen to the launch vehicle, a planned 1-hour hold was called for another weather evaluation. The weather evaluation was favorable and the countdown proceeded from T−180 minutes at 3:00 a.m. e.s.t. No further delays in the countdown were encountered until T−45 minutes. A 30-minute hold was called at this time to install a misalined hatch bolt. At T−30 minutes, a 9-minute hold was required to turn off the pad searchlights which interfere with launch-vehicle telemetry during launch. At T−15 minutes, a 41-minute hold was required to await better cloud conditions. The count then proceeded from T−15 until lift-off.

The pilot was in the spacecraft 3 hours and 22 minutes prior to launch.

Flight Description

The MR–4 flight plan was very much the same as that for the MR–3. The flight profile is shown in figure 2–5. As shown, the range was 262.5 nautical miles, the maximum altitude was 102.8 nautical miles, and the period of weightlessness lasted for approximately 5 minutes.

The sequence of events was as follows:

At T−35 seconds, the spacecraft umbilical was pulled and the periscope was retracted. During the boosted phase of flight, the flight-path angle was controlled by the launch-vehicle control system. Launch-vehicle cutoff occurred at T+2 minutes 23 seconds, at which time the escape tower clamp ring was released, and escape tower was released by firing the escape and tower jettison rockets. Ten seconds later, the spacecraft-to-launch-vehicle adapter clamp ring was separated, and the posigrade rockets fired to separate the spacecraft from the launch vehicle. The periscope was extended; the automatic stabilization and control system provided 5 seconds of rate damping, followed by spacecraft turnaround. It then oriented the spacecraft to orbit attitude of −34°.

Retrosequence was initiated by timer at T+4 minutes 46 seconds, which was 30 seconds prior to the spacecraft reaching its apogee.

The astronaut assumed control of spacecraft attitude at T+3 minutes 5 seconds and controlled the spacecraft by the manual proportional control system to T+5 minutes 43 seconds. He initiated firing of the retrorockets at T+5 minutes 10 seconds. From T+5 minutes 43 seconds, he controlled the spacecraft by the manual rate command system through reentry. The retrorocket package was jettisoned at T+6 minutes 7 seconds. The drogue parachute was deployed at T+9 minutes 41 seconds, and main parachute, at T+10 minutes 14 seconds. Landing occurred at T+15 minutes 37 seconds.

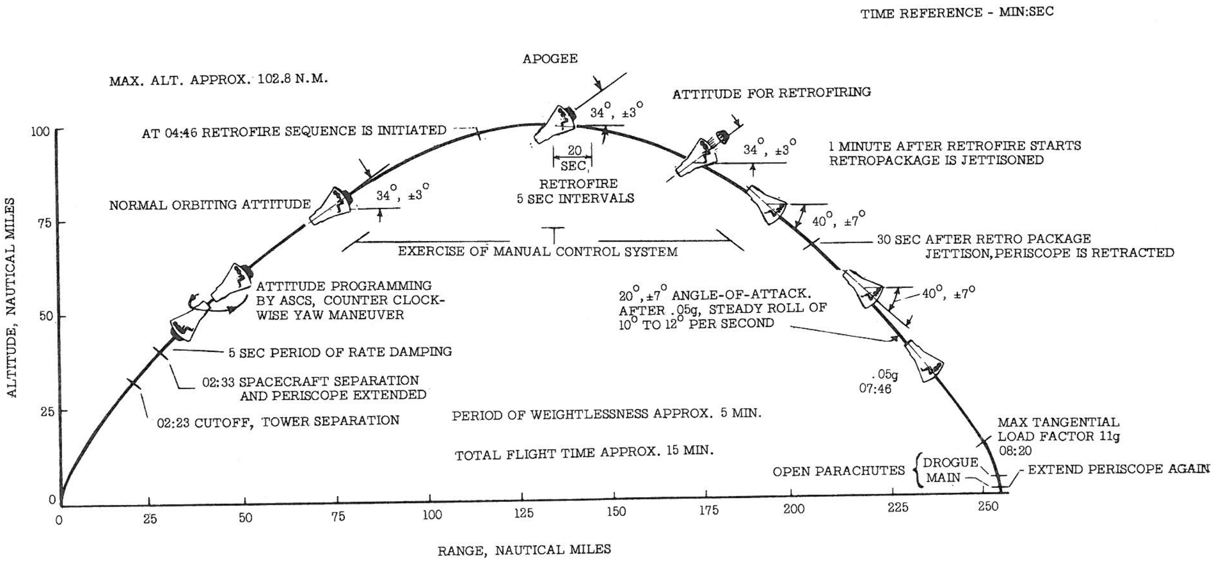

FIGURE 2–5. Flight profile for MR–4.

A comparison of the flight parameters of MR–4 and MR–3 spacecraft, listed in table 2–I, shows that both flights provided similar conditions.

TABLE 2–I.—*Comparison of Flight Parameters for MR–3 and MR–4 Spacecraft*

Parameter	MR–3 flight	MR–4 flight
Range, nautical miles	263.1	262.5
Maximum altitude, nautical miles	101.2	102.8
Maximum exit dynamic pressure, lb/sq ft	586.0	605.5
Maximum exit longitudinal load factor, g units	6.3	6.3
Maximum reentry longitudinal load factor, g units	11.0	11.1
Period of weightlessness, min:sec	5:04	5:00
Earth-fixed velocity, ft/sec	6,414	6,618
Space-fixed velocity, ft/sec	7,388	7,580

The acceleration time history occurring during the MR–4 flight is shown in figure 2–6 and is very similar to that of the MR–3 flight (ref. 1).

The recovery-force deployment and spacecraft landing point are shown in figure 2–7. The spacecraft was lost during the postlanding recovery period as a result of premature actuation of the explosively actuated side egress hatch. The astronaut egressed from the spacecraft immediately after hatch actuation and was retrieved after being in the water for about 3 to 4 minutes.

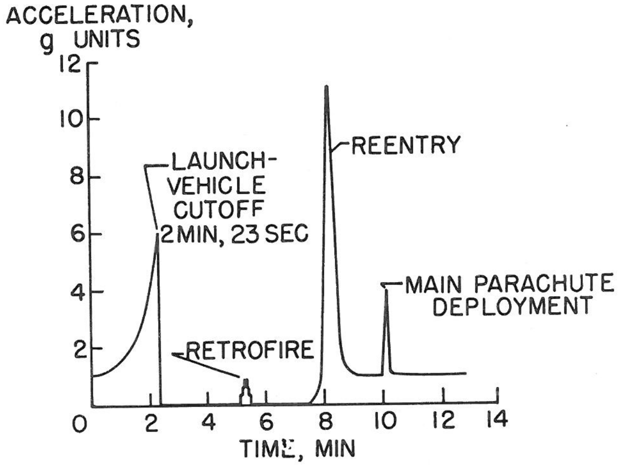

FIGURE 2–6. Acceleration time history for MR–4 flight.

The spacecraft and its systems performed well on the MR–4 flight; the major difficulty was the as yet unexplained premature separation of the side egress hatch. A minor control problem was noted in that design turning rates were not achieved with full stick deflection. This problem is believed to be due to control linkage rigging.

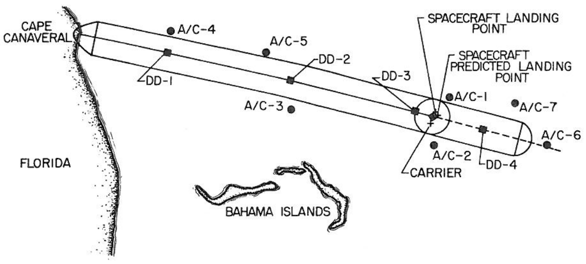

FIGURE 2–7. Chart of recovery operations.

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3. RESULTS OF THE MR–4 PREFLIGHT AND POSTFLIGHT MEDICAL EXAMINATION CONDUCTED ON ASTRONAUT VIRGIL I. GRISSOM

By William K. Douglas, M.D., *Astronaut Flight Surgeon, NASA Manned Spacecraft Center;* Carmault B. Jackson, Jr., M.D., *Life Systems Division, NASA Manned Spacecraft Center;* Ashton Graybiel, M.D., *USN School of Aviation Medicine, Pensacola, Fla.;* George Ruff, M.D., *University of Pennsylvania;* Edward C. Knoblock, Ph. D., *Walter Reed Army Medical Center;* William S. Augerson, M.D., *Life Systems Division, NASA Manned Spacecraft Center;* and C. Patrick Laughlin, M.D., *Life Systems Division, NASA Manned Spacecraft Center*

This paper presents the results of the clinical and biochemical examinations conducted on Astronaut Virgil I. Grissom prior to and following the MR–4 mission. The objectives of such an examination program were presented in the MR–3 report on Astronaut Alan B. Shepard, Jr. (ref. 1). Basically, the health of the astronaut before and after the space flight was assessed and any alterations were sought out that might have resulted from the stresses imposed by the space flight. Similar medical and biochemical examinations had been accomplished during the Mercury-Redstone centrifuge training sessions and provided data of comparative value.

It is important to point out the limitations in correlating examination findings with specific flight stresses. The last preflight examination was performed approximately 5 hours before lift-off and the final postflight examination 3 hours after spacecraft landing. The strenuous effort by Astronaut Grissom during his recovery from the ocean may well have produced changes which overshadowed any flight induced effects.

Astronaut Grissom was examined several times in the preflight period as two launch attempts were canceled before the actual flight on July 21, 1961. The initial clinical and biochemical examinations were performed on July 17, 1961, at which time questioning disclosed no subjective complaints. Positive physical findings were limited to shotty, nontender inguinal and axillary adenopathy, and mild pharyngeal lymphoid hyperplasia. The skin at the lower sternal electrode placement site exhibited a well circumscribed area (1 cm in diameter) of eruption. This lesion appeared to consist of about 8 to 10 small pustules arising from hair follicles. Upon closer examination of this eruption in August 1961, it became apparent that the pustules seen in July had, by this later date, become inclusion cysts. Culture of these lesions in August 1961 was sterile. These lesions were attributed to the use of electrode paste and were also noted on the pilot of MR–3 flight.

The preflight examination on July 21, 1961, is reported in detail. A feeling of mild "sore throat" was reported; otherwise the body systems review was negative. Psychiatric examination reported "no evidence of overt anxiety, that Astronaut Grissom explained that he was aware of the dangers of flight, but saw no gain in worrying about them." In fact, "he felt somewhat tired, and was less concerned about anxiety than about being sufficiently alert to do a good job." At the physical examination the vital signs (table 3–I) were an oral temperature of 97.8° F, blood pressure of 128/75 (right arm sitting), weight of 150.5 lb, pulse rate of 68, and respiration rate of 12. Inspection of the skin revealed there were small pustules at the site of the lower sternal electrode, but it was otherwise clear. The same shotty nontender inguinal and axillary nodes were felt. Eye, ear, nose, and mouth examination was negative. There was slight to moderate oropharyngeal lymphoid hyperplasia. The trachea was midline, the neck normally flexible, and the thyroid gland unremarkable. The lungs were clear to percussion and auscultation throughout. Heart sounds were of normal quality, the rhythm was regular, and the heart was not enlarged to percussion. Palpitation of the abdomen revealed no spasm, tenderness, or abnormal masses. The genitalia, back, and extremities were normal. Calf and thigh measurements were:

	Calf	Thigh
Right	15⅞ in.	21 in.
Left	15⅞ in.	20¾ in.

Neurological examination revealed no abnormality. An electroencephalogram, electrocardiogram, and chest X-ray were normal, unchanged from September 1960. Vital capacity standing, measured with a bellows spirometer, was 5.0 liters. Analysis of the urine and blood (tables 3–II and 3–III) revealed no abnormality.

As with the MR–3 flight, members of the medical examining team were either transported to the Grand Bahama Island debriefing site a day prior to launch or flew down immediately after launch.

The initial postflight medical examination was conducted immediately after Astronaut Grissom arrived aboard the recovery aircraft carrier, USS *Randolph,* approximately 15 minutes after spacecraft landing in the ocean. The examination was conducted by the same physicians who examined Astronaut Shepard aboard the USS *Lake Champlain.*

The findings disclosed vital signs of rectal temperature of 100.4° F; pulse rate from 160 initially to 104 (supine at end of examination); blood pressure of 120/85 LA sitting, 110/88 standing, and 118/82 supine; weight of 147.2 pounds, and respiratory rate of 28. On general inspection, the astronaut appeared tired and was breathing rapidly; his skin was warm and moist. Eye, ear, nose, and throat examination revealed slight edema of the mucosa of the left nasal cavity and no other abnormalities. Chest examination showed no signs of atelectasis although there was a high noise level in the examining room. No rales were heard and the pilot showed no tendency to cough. Vital capacity measured with a bellows spirometer while still in suit was 4.5 liters.

Peripheral pulses were described as normal and a left axillary node was noted. The abdomen was soft with normal bowel sounds.

The pilot voided three times without fluid intake. The limited neurological examination disclosed no abnormalities. Extremity measurements were as follows:

	Calf	Thigh
Right	15¼ in.	20½ in.
Left	15¼ in.	20¾ in.

After a short nap and breakfast he was flown to Grand Bahama Island, arriving approximately 3 hours after spacecraft landing. His general appearance was much improved. Vital signs were recorded as a temperature of 98.4 (oral); blood pressure of 125/85 sitting, 124/82 standing, 122/78 supine; pulse rate of 90; and weight of 147.5 pounds.

Ophthalmological examination approximately 6 hours postflight showed slight injection of the conjunctiva of the left eye. These findings, as well as nasal mucosa edema, were ascribed to salt water exposure. The lungs remained clear to percussion and auscultation. The abdomen, genitalia, back, and extremities were normal. Neurological examination revealed "changes consistent with muscular fatigue in a normal individual." The electroencephalogram, electrocardiogram, and chest X-ray revealed no abnormality. Vital capacity measurement was 4.8 and 4.9 liters. An exercise tolerance test (Harvard step) was within control range.

Additional examinations in the ensuing 48 hours revealed no changes when compared with preflight studies.

The vital signs are summarized in table 3–I. Results of the biochemical determination are presented in tables 3–II to 3–V. Control data from Redstone centrifuge experience are included.

Table 3–VI shows comparisons between clinical observations from single simulated Redstone missions conducted at the Johnsville human centrifuge (with a 5-psia 100-percent oxygen environment) and the MR–4 flight. The examinations were made before and after the simulation, at times comparable to those in the actual flight.

An evaluation of the clinical and biochemical studies permits the following conclusions:

(a) Astronaut Grissom was in good health prior to and following his MR–4 flight. The immediate postflight examination revealed changes consistent with general fatigue and sea water exposure.

(b) Clinical examination disclosed no specific functional derangement that could be attributed to the spaceflight stresses.

(c) No specific biochemical alteration occurred that could be attributed to a spaceflight stress effect.

Acknowledgments—Special acknowledgment is paid to Drs. Robert C. Lanning (USN) and Jerome Strong (USA) who conducted the physical examination aboard the USS *Randolph;* Dr. James F. Culver of the USAF School of Aviation Medicine, who performed the ophthalmologic examinations; Dr. Phillip Cox, Andrews Air Force Base Hospital, who participated in the physical examinations; and Dr. Francis Kruse of the Lackland Air Force Base Hospital, who performed the neurological examinations. Dr. Walter Frajola of Ohio State Univer-

sity made some of the biochemical determinations, and Miss Rita Rapp, Life Systems Division, NASA Manned Spacecraft Center, collected and processed the biochemical specimens.

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TABLE 3–I.—*Vital Signs*

	Preflight	Postflight	
	−7 hr (Cape Canaveral)	+30 min (Shipboard)	+2 hr (Grand Bahama Island)
Body weight nude (post voiding)	150 lb 8 oz	147 lb 3 oz	147 lb 8 oz
Temperature, °F	97.8 (oral)	100.4 (rectal)	98.4 (oral)
Pulse per min	68	160 to 104	90
Respiration per min	12	28	14
Blood pressure, mm Hg:			
Sitting	128/75	120/85	125/85
Standing		110/88	124/82
Supine		118/82	122/78
Vital capacity (bellows spirometer), liters	5.0	4.5	4.8 4.9

TABLE 3-II.—*Results of Urine Tests*

	Centrifuge			MR-4 flight							
	Pre-run	Postrun		Preflight		Postflight					
		+30 min	+2 hr	−6 hr	During count-down	+1 hr	+3 hr	+6 hr	+13 hr	+24 hr	+26 hr [1]
Sample volume, ml	125	185	470	135	185	110	300	100	475	135	315
Specific gravity	1. 023	1. 005	1. 011	1. 020	1. 011	1. 010	1. 022	1. 020	1. 022	1. 025	1. 015
Albumin	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Glucose	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Ketones	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Occult blood	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
pH	6. 4	6. 2	6. 2	6. 6	6. 8	6. 4	6. 0	6. 0	6. 0	6. 0	6. 8
Na, mEq/L	130	28	79	142	76	70	122	128	140	114	140
K, mEq/L	62	28	39	35	18	19	37	39	25	49	71
Cl, mEq/L	...	...	...	55	68	130	65	111	68	69	178
Microscopic examination	No formed elements observed										

[1] Breakfast eaten following previous sample.

TABLE 3-III.—*Peripheral Blood Findings*

	Preflight	Postflight		
	−3 days	+1 hr	+5 hr	+49 hr
Hematocrit, percent	42. 5	42. 2	42. 5	42. 7
Hemoglobin,[1] g	14. 1	14. 4	14. 6	14. 2
White blood cells, per mm³	6, 500	7, 200	9, 100	6, 700
Red blood cells, millions/mm³	4. 81	4. 75	4. 67	4. 71
Differential blood count:				
Lymphocytes, percent	46	40	29	35
Neutrophiles, percent	46	54	66	59
Band cells, percent	....	....	....	....
Monocytes, percent	5	4	3	4
Eosinophiles, percent	1	2	2	2
Basophiles, percent	2	0	0	0

[1] Acid Hematin method.

Table 3-IV.—*Blood Chemistry Findings*

	Centrifuge			MR-4 flight			
	Prerun	Postrun		Preflight	Postflight		
		+30 min	+2 hr	−4 days	+1 hr	+5 hr	+49 hr
Sodium (serum), mEq/L	147	141	143	142	140	144	141
Potassium (serum), mEq/L	5. 4	5. 9	4. 6	4. 1	3. 5	4. 4	4. 8
Chloride, mEq/L	89	94	90	97	95	101	99
Protein, total	7. 5	8. 0	7. 6	7. 4	7. 3	7. 1	7. 9
Albumin, g/100 ml	4. 1	4. 3	4. 0	3. 25	4. 2	5. 0	4. 2
Globulin, g/100 ml	3. 4	3. 7	3. 6	4. 15	3. 1	2. 1	4. 7
Glucose, mg/100 ml	78	118	95	94	136	105	....
Epinephrine,[1] μg/L	<0. 1	<0. 1	<0. 1	<0. 1	<0. 1	<0. 1	....
Norepinephrine,[2] μg/L	2. 3	7. 2	1. 5	5. 1	16. 5	7. 2	....

[1] Normal values: 0. 0 to 0. 4 μg/L
[2] Normal values; 4. 0 to 8. 0 μg/L

Table 3-V.—*Plasma Enzymes Determinations*

	Normal range, units	Centrifuge			MR-4 flight		
		Prerun	Postrun		Preflight	Postflight	
			+30 min	+2 hr	−4 days	+3 hr	+49 hr
Transaminases:							
SGOT	0 to 35	15	19	13	19	21	28
SGPT	0 to 20	8	8	8	6	6	7
Esterase acetylcholine	[1] 130 to 260	260	215	280	225	205	165
Peptidase leucylamino	100 to 310	190	250	200	370	375	385
Aldolase	50 to 150	19	28	22	6	13	3
Isomerase phosphohexose	[2] 10 to 20	....	....	....	42	86	17
Dehygrogenases:							
Lactic	150 to 250	170	155	190	190	250	220
Malic	150 to 250	140	220	170	235	275	220
Succinic	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Inosine	Neg.	Neg.	Neg.	Neg.	....	....	....
Alpha-ketoglutaric	Neg.	Neg.	Neg.	Neg.	....	....	....
Isocitric	0 to 10	....	....	....	3	6	3
L-Glutamic	0 to 10	....	....	....	11	3	11
Alk phos	....	....	....	....	4	3	8

[1] ΔpH units.
[2] Bodansky units.

TABLE 3–II.—*Results of Urine Tests*

	Centrifuge			MR–4 flight							
	Pre-run	Postrun		Preflight		Postflight					
		+30 min	+2 hr	−6 hr	During count-down	+1 hr	+3 hr	+6 hr	+13 hr	+24 hr	+26 hr [1]
Sample volume, ml	125	185	470	135	185	110	300	100	475	135	315
Specific gravity	1. 023	1. 005	1. 011	1. 020	1. 011	1. 010	1. 022	1. 020	1. 022	1. 025	1. 015
Albumin	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Glucose	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Ketones	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Occult blood	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
pH	6. 4	6. 2	6. 2	6. 6	6. 8	6. 4	6. 0	6. 0	6. 0	6. 0	6. 8
Na, mEq/L	130	28	79	142	76	70	122	128	140	114	140
K, mEq/L	62	28	39	35	18	19	37	39	25	49	71
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Microscopic examination	No formed elements observed										

[1] Breakfast eaten following previous sample.

TABLE 3–III.—*Peripheral Blood Findings*

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White blood cells, per mm^3	6, 500	7, 200	9, 100	6, 700
Red blood cells, millions/mm^3	4. 81	4. 75	4. 67	4. 71
Differential blood count:				
Lymphocytes, percent	46	40	29	35
Neutrophiles, percent	46	54	66	59
Band cells, percent	....	....	....	....
Monocytes, percent	5	4	3	4
Eosinophiles, percent	1	2	2	2
Basophiles, percent	2	0	0	0

[1] Acid Hematin method.

TABLE 3–VI.—*Comparison of Physical Examination Findings During Simulated and Actual Flight*

	Simulated Redstone I	Simulated Redstone II	MR–4 flight
Temperature, °F:			
Before	97.9	97.4	97.8
After	99.0	98.0	98.4
Change	1.1	0.6	0.6
Weight, lb:			
Before	150.31	148.25	150.5
After	147.10	146.36	147.5
Loss	3.21	1.89	3.0
Pulse rate per min:			
Before	68	69	68
After	82	84	160 to 104
Blood pressure (LA), mm Hg:			
Before	110/68	100/70	128/75
After	100/70	128/80	120/84
Vital capacity, liters:			
Before	5.9		5.0
After	5.4		4.5
Postflight physical findings	Chest clear to P and A; slightly increased DTR's; no change in ECG; no petechia; appears warm and tired.	Chest clear; DTR's 2+; no petechia.	Chest clear; no petechia; appeared fatigued.

4. PHYSIOLOGICAL RESPONSES OF THE ASTRONAUT IN THE MR–4 SPACE FLIGHT

By C. Patrick Laughlin, M.D., *Life Systems Division, NASA Manned Spacecraft Center;* and William S. Augerson, M.D., *Life Systems Division, NASA Manned Spacecraft Center*

Objectives

The space flight of Mercury-Redstone 4 accomplished several life-science objectives. Specifically, a second United States astronaut experienced the complex stresses associated with manned space flight; physiological data reflecting the responses of a second United States astronaut to space flight were obtained; and additional experience was gained in the support of manned space flight which will influence procedures in subsequent operations.

The Space Flight Environment

After two attempts at launching in the 4 days preceding the flight, Astronaut Grissom entered the spacecraft at 3:58 a.m. e.s.t. on July 21, 1961. His preparation had proceeded smoothly, beginning at 1:10 a.m. e.s.t. as discussed in paper 5. He was wearing the Mercury full-pressure suit and was positioned in his contour couch in the semisupine position, with head and back raised approximately 10° and legs and thighs flexed at approximately 90° angles. This position was maintained until egress from the spacecraft after landing. One-hundred-percent oxygen was supplied when pressure suit connections to the spacecraft environmental control system were completed. The total time in the spacecraft during the countdown was 3 hours 22 minutes. During the extended countdown, Astronaut Grissom performed numerous spacecraft checks and "relaxed" with periodic deep breathing, muscle tensing, and movement of his limbs. At the lift-off signal, the Redstone launch vehicle ignited and accelerated smoothly, attaining a peak of 6.3g at T + 2 minutes 22 seconds. Then the spacecraft separated from the launch vehicle and gravity forces were abruptly terminated. A period of 5 seconds ensued while spacecraft turnaround and rate damping occurred. During the 5 minutes of weightless flight which followed, Astronaut Grissom was quite active in performing vehicle control maneuvers and with monitoring of spacecraft systems. He was, in his own words, "fascinated" with the view from the spacecraft window. The firing of the retrorockets at T+5 minutes 10 seconds resulted in a brief 1g deceleration. At T + 7 minutes 28 seconds the 0.05g relay signaled the onset of reentry, and deceleration forces climbed quickly to 11g. Drogue and main parachute actuation occurred at T + 9 minutes 41 seconds and T + 10 minutes 13 seconds, respectively, and a 4g spike was seen with opening of the main parachute. Landing occurred at T + 15 minutes 37 seconds, 7:35 a.m. e.s.t.

Suit and cabin pressure levels declined rapidly from launch ambient levels, as programed, and stabilized at approximately 5 psia with the suit pressure slightly above cabin pressure. These pressures were maintained until snorkle valve opening at T + 9 minutes 30 seconds during parachute descent.

Suit inlet temperature ranged from 55° F to 62° F during countdown and flight and reached a level of 73° F after approximately 9 minutes on the water after landing.

Monitoring and Data Sources

Medical monitoring techniques and biosensor application were identical with those utilized in the MR–3 mission (ref. 1). The total monitoring time was approximately 3 hours and 35 minutes, commencing with entrance into the spacecraft and ending in loss of signal after landing. Physiological data were monitored from the medical consoles in Mercury Control Central and the Redstone blockhouse, and signals were received during the later flight stages at Bermuda and on downrange ships. Again the astronaut's inflight voice transmissions and postflight debriefing were particularly significant as data sources. (Samples of inflight telemetry data recorded at various monitoring stations are shown in figs. 4–1 to 4–4.) In addition, the

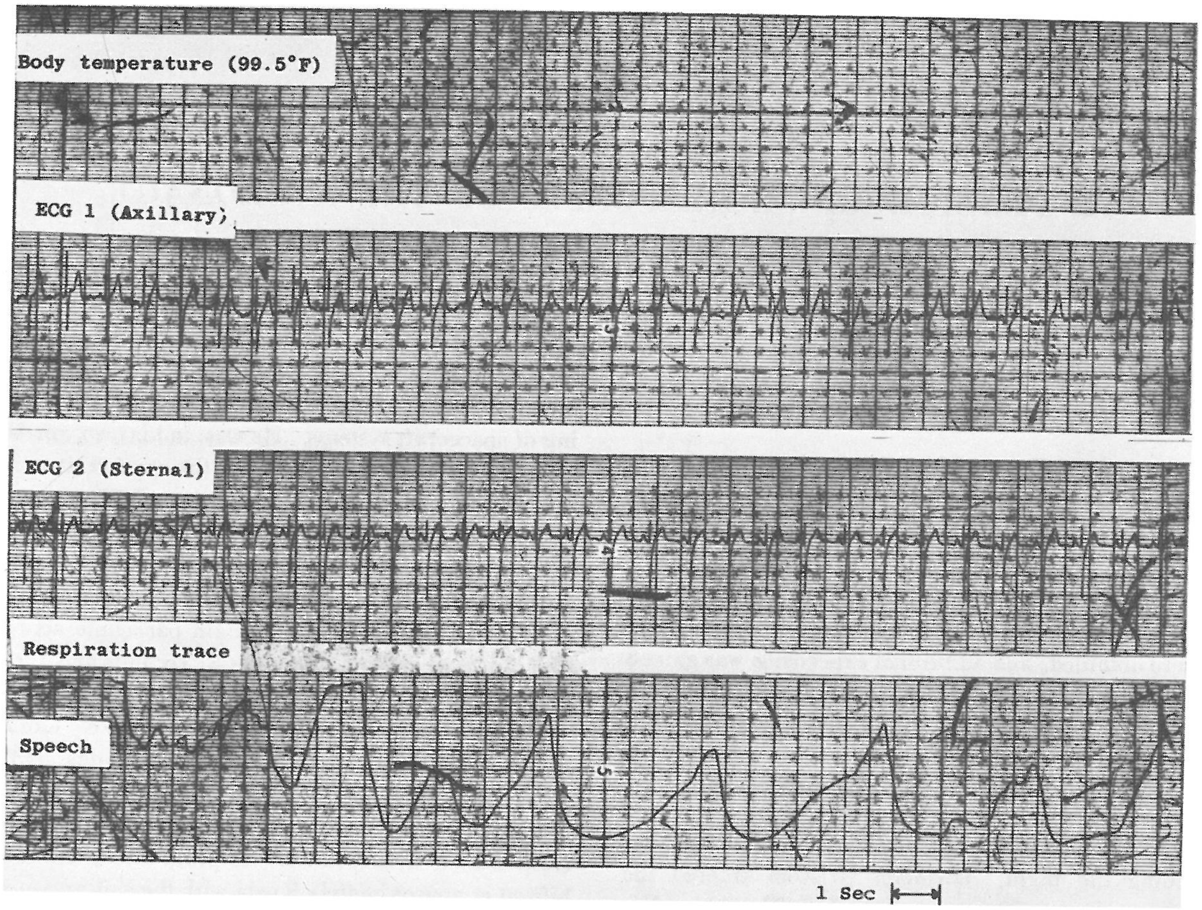

FIGURE 4–1. Blockhouse telemetry record obtained during countdown (5:43 a.m. e.s.t.).

canceled mission of July 19 with 4 hours of countdown provided interesting comparative physiological data. Astronaut Grissom's physiologic responses to 17 Mercury-Redstone g-profile centrifuge runs were also available as dynamic control data. Unfortunately, the astronaut observer camera film was lost with the sunken spacecraft.

Results of Observations of Physiological Function

Figures 4–5 and 4–6 depict the pulse rate during the countdown, tabulated by a 10-second duration pulse count for each minute of count time. Pulse rates occurring at similar events in the canceled mission countdown are also indicated. The countdown pulse rate ranged from 65 to 116 per minute until shortly before lift-off. As plotted in figure 4–7, pulse rate began accelerating from T−1 minutes through launch, attaining a rate of 162 beats per minute at spacecraft separation and turnaround maneuver. Some slight rate decline trend was apparent during the first 2 minutes of weightlessness, returning to a high of 171 beats per minute with retrorocket firing. The pulse rate was above 150 beats per minute during all but a few seconds of weightlessness. Pulse rate declined slightly following reentry deceleration and then fluctuated considerably during parachute descent and was 137 beats per minute on landing. All inflight pulse rates were determined every 15 seconds, counting for 10-second durations.

Electrocardiographic trace quality from both sternal and axillary leads was quite satisfactory during countdown and flight. Sinus tachycardia and occasional sinus arrhythmia were present. No abnormalities of rhythm or wave form were observed.

Respiratory rate during countdown varied from 12 to 24 breaths per minute as shown in figures 4–5 and 4–6. Unfortunately, respiratory trace quality, which had been quite acceptable during countdown, deteriorated during most of the flight, precluding rate tabulation. Some readable trace returned late in the flight, and a high of 32 breaths per minute was noted.

Body temperature (rectal) varied from 99.5° immediately after astronaut entry into the spacecraft

to 98.6° just before launch. There was a gradual increase to 99.2° in the latter phases of flight. These changes are considered to be insignificant, and, subjectively, temperature comfort was reported to be quite satisfactory during the countdown and flight.

Astronaut Grissom made coherent and appropriate voice transmissions throughout the flight. At the postflight debriefing, he reported a number of subjective impressions gained while in flight. He noted that the vibration experienced at maximum dynamic pressure was "very minor" and did not interfere with vision. A brief tumbling sensation was noted at launch-vehicle cutoff. This sensation was only momentary and was not accompanied by nausea or disturbed vision. A distinct feeling of sitting upright and moving backward was described and the sensation reversed to forward travel with retrorocket firing. This orientation may have been related to his position relative to Cape Canaveral; that is, observing the Cape receding behind through the spacecraft window. No disturbances in well-being were reported during the flight and the absence of gravity produced no specifically recognized symptoms. The astronaut was not aware of his heart beating throughout the mission. Hearing was adequate throughout the flight according to pilot reports and voice responses. Near and distant visual acuity and color vision appeared to be normally retained. The jettisoned escape tower was followed for several seconds through the spacecraft

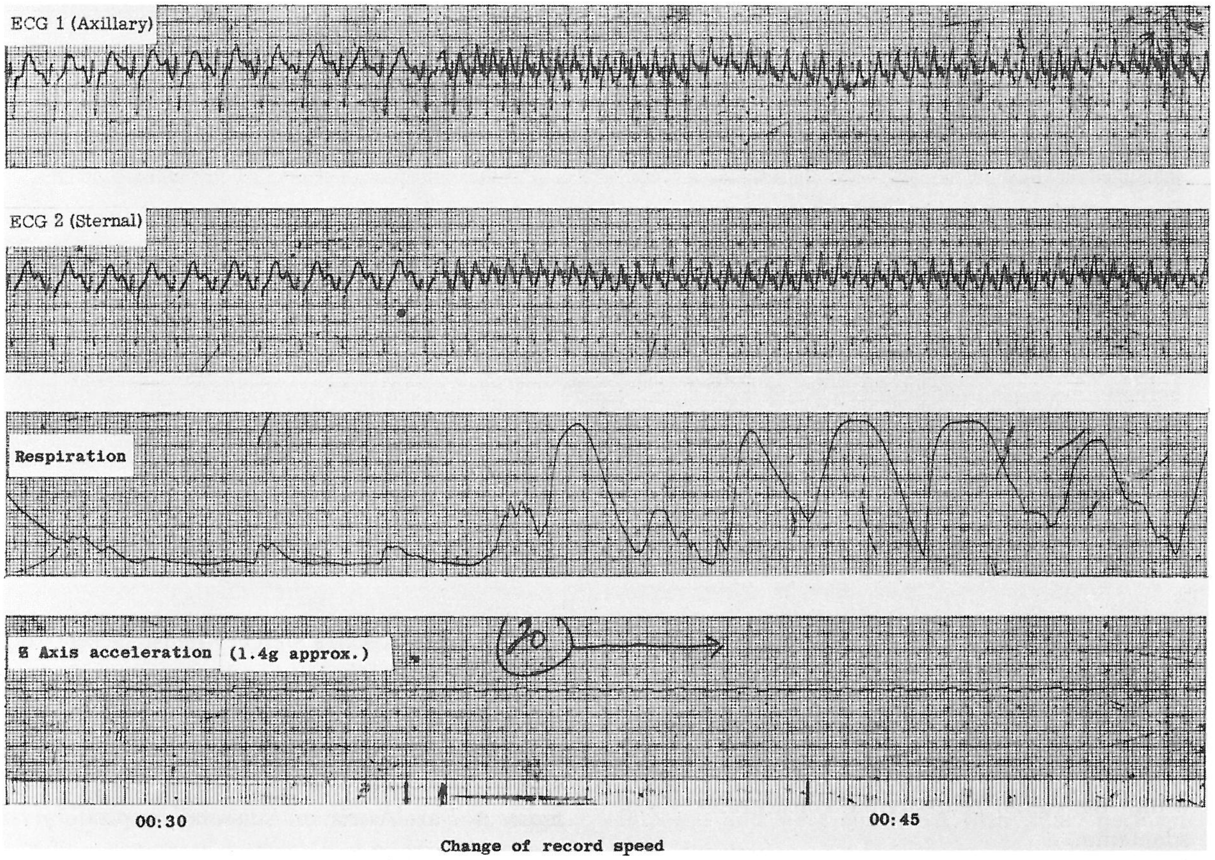

FIGURE 4–2. Mercury Control Center record during launch phase (00:30 to 00:45). First part of record at 25 mm/sec, second part at 10 mm/sec.

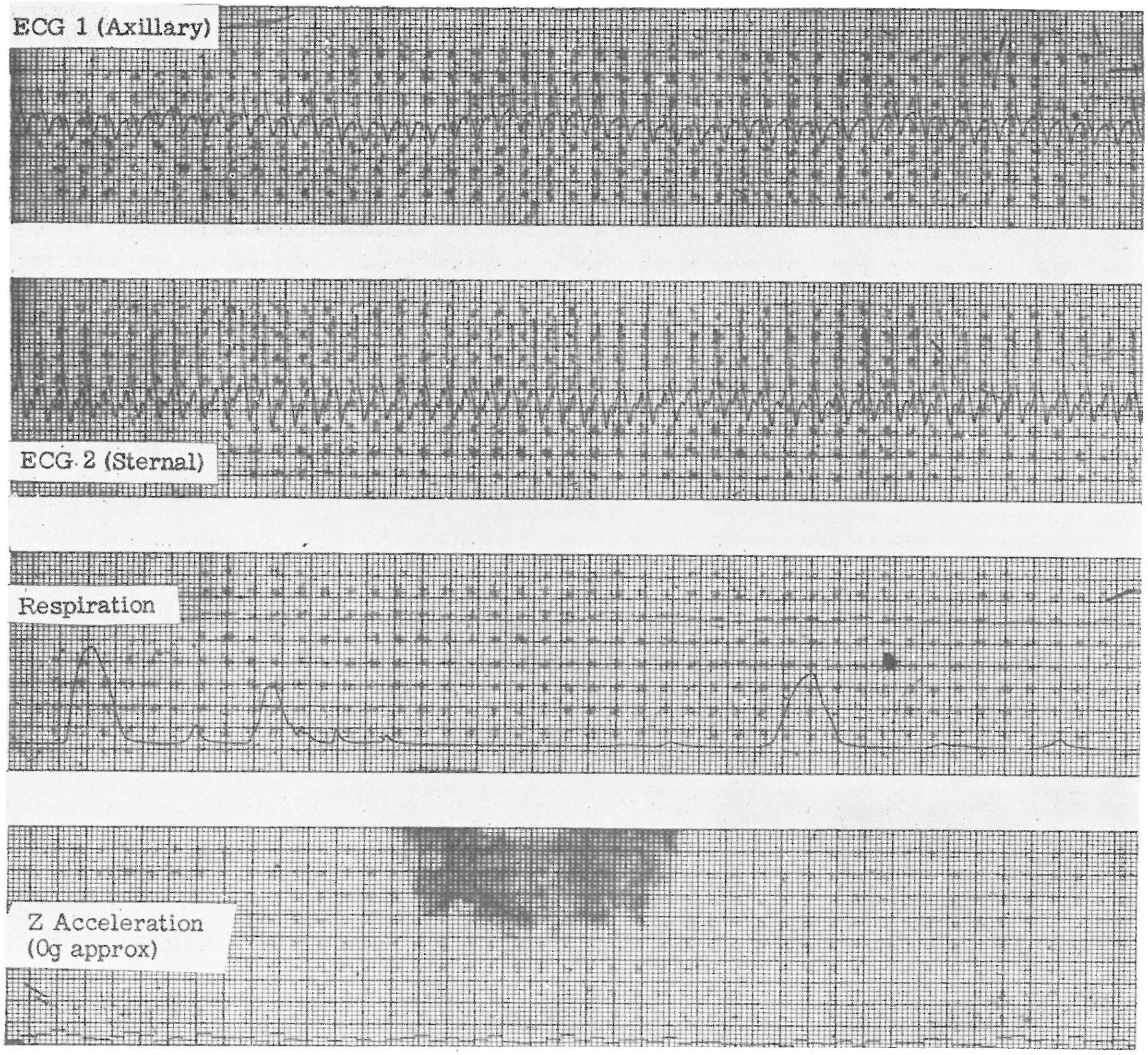

FIGURE 4–3. Bermuda Mercury Station record (10 mm/sec) taken just before 0.05g as period of weightlessness was nearing end.

window and a planet (Venus) was observed just before burnout. Vivid contrasting color was reported during observation of the sky and earth. The programed turnaround and other maneuvers of the spacecraft produced changing levels of illumination within the cabin, necessitating considerable visual adaptation.

Improved environmental control system instrumentation permitted a determination of astronaut oxygen consumption during the countdown. This was calculated to be about 500 cc/min. A very high usage rate was noted during flight as a result of system leakage, and metabolic utilization could not be determined.

Astronaut Grissom's Mercury-Redstone centrifuge pulse rates were tabulated and are presented graphically in figure 4–7 for comparison with the flight pulse data. The highest rate noted for his centrifuge experience was 135 beats per minute. Also shown in figure 4–7 are Astronaut Grissom's respiratory rate responses during four Mercury-Redstone centrifuge sessions.

Conclusions

An evaluation of the physiological responses of the astronaut of the MR–4 space flight permits the following conclusions:

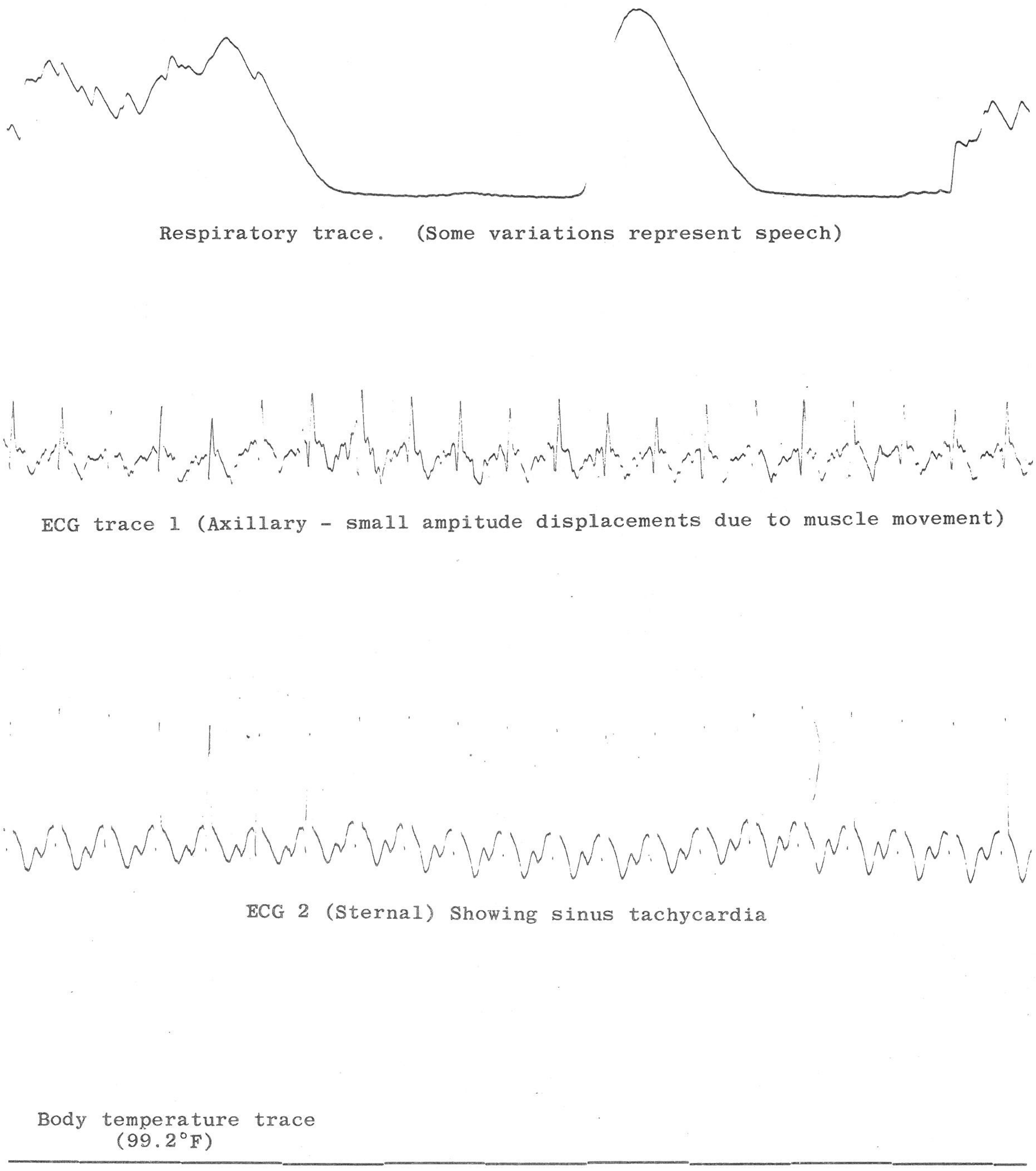

FIGURE 4-4. Telemetry-aircraft record obtained 9 minutes after reentry.

(1) There is no evidence that the space flight stresses encountered in the MR-4 mission produced detrimental physiological effects.

(2) The pulse-rate responses reflected Astronaut Grissom's individual reaction to the multiple stresses imposed and were consistent with intact performance function.

(3) No specific physiologic findings could be attributed to weightlessness or to acceleration-weightlessness transition stresses.

Reference

1. HENRY, JAMES P., and WHEELWRIGHT, CHARLES D.: *Bioinstrumentation in MR-3 Flight.* Proc. Conf. on Results of the First U.S. Manned Suborbital Space Flight, NASA, Nat. Inst. Health, and Nat. Acad. Sci., June 6, 1961, pp. 37-43.

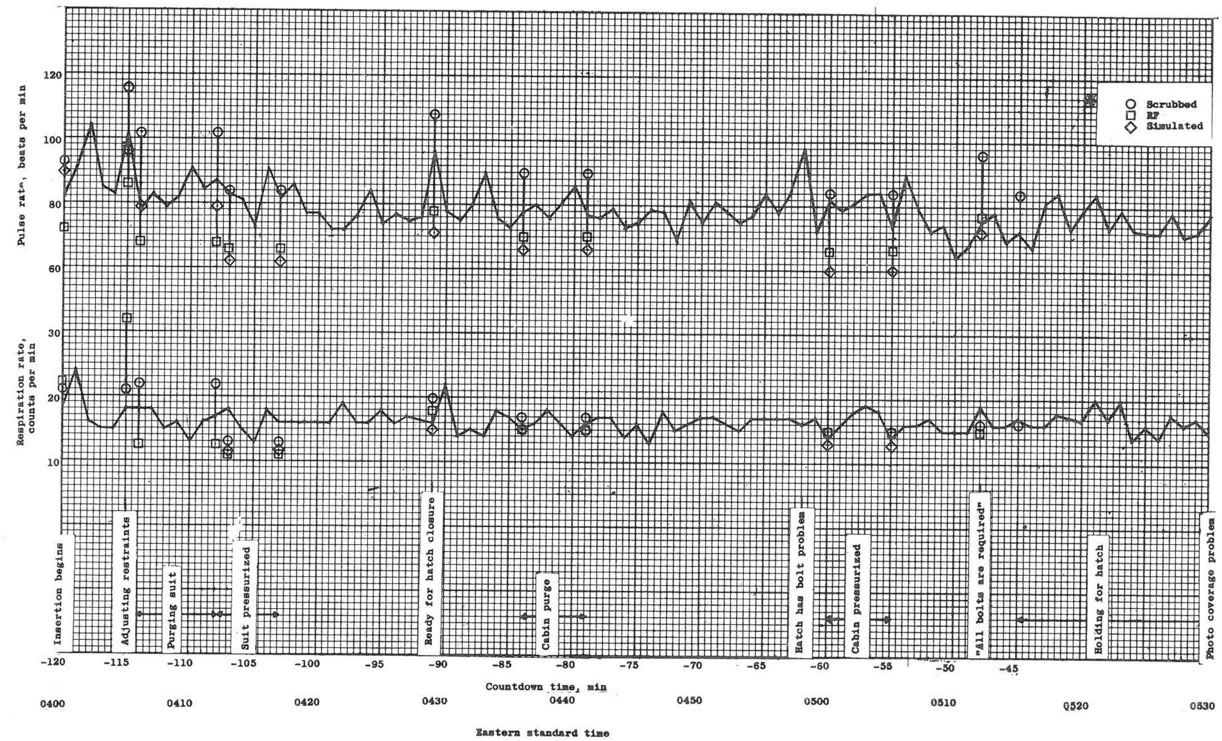

FIGURE 4–5. Pulse and respiration rates during countdown (4:00 to 5:30 a.m. e.s.t.).

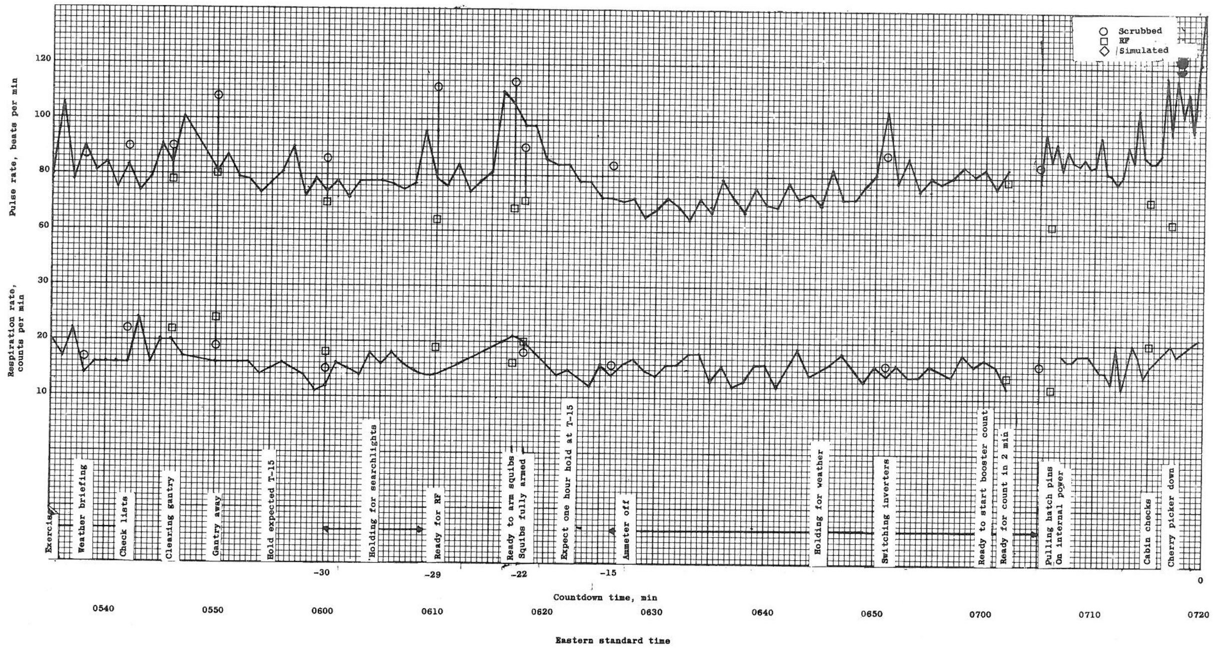

FIGURE 4–6. Pulse and respiration rates during countdown (5:40 to 7:20 a.m. e.s.t.).

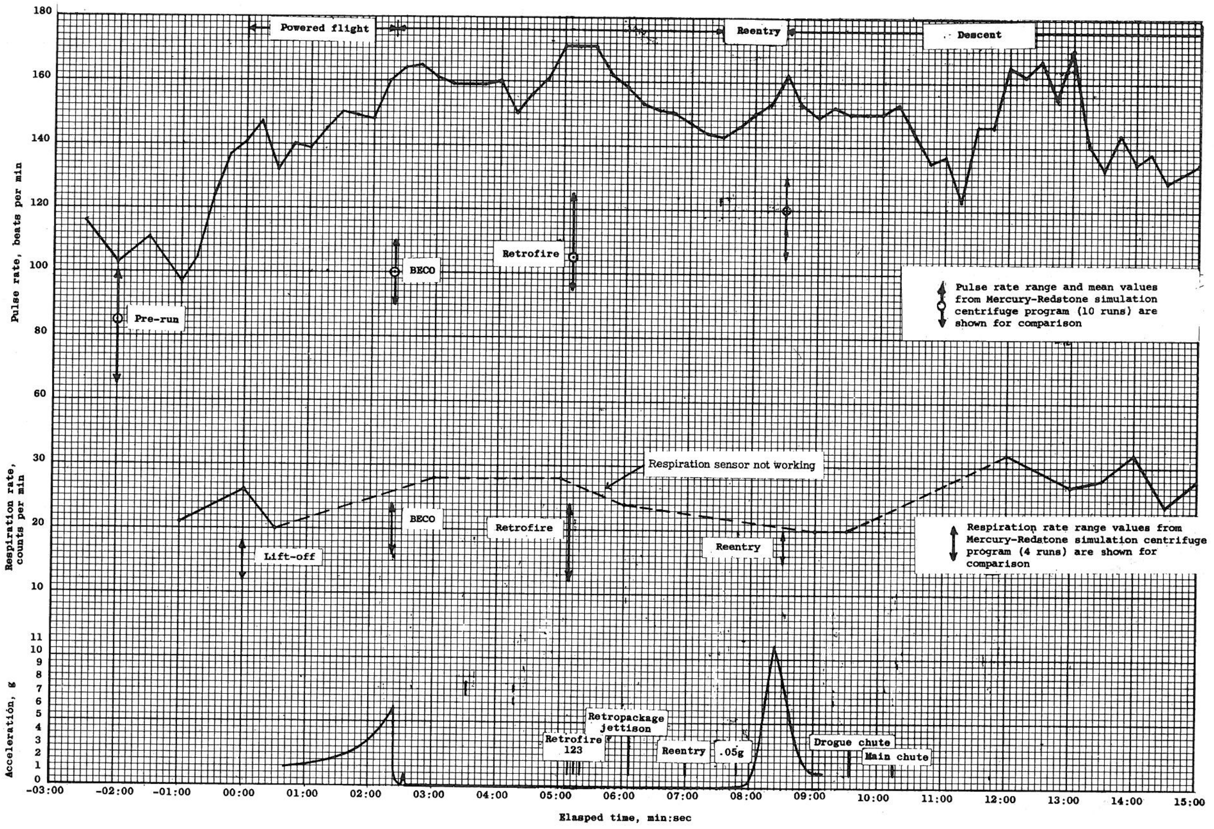

FIGURE 4–7. Pulse and respiration rates during flight.

5. FLIGHT SURGEON'S REPORT FOR MERCURY-REDSTONE MISSIONS 3 AND 4

By William K. Douglas, M.D., *Astronaut Flight Surgeon, NASA Manned Spacecraft Center*

Introduction

This paper describes some of the operational aspects of the medical support of the two manned suborbital space flights, designated Mercury-Redstone 3 and Mercury-Redstone 4. The results of the medical investigative procedures are reported in paper 3 of the present volume and in reference 1. These operational aspects can be conveniently divided into three phases:

(a) The early preparation period beginning about 3 days before a launch and concluding at about T − 12 hours

(b) The immediate preflight preparation

(c) The debriefing period

Preparation of the Pilot

Part of the philosophy behind the decision to execute manned suborbital space flights was to provide experience and practice for subsequent orbital flights. In light of this philosophy, it was decided that during suborbital flights all preparations will be made for the orbital flight. This explains the reason for such things as the low residue diet and other seemingly inappropriate steps in the preparation and support of the pilot.

Three days before the planned launch day, the pilot and the backup pilot start taking all of their meals in a special feeding facility. Here, a special low residue diet is provided. Preparation of this diet is supervised by an accredited dietitian, and the actual preparation is performed by a cook whose sole duty during this period is to prepare these meals. One extra serving of each item is prepared for each meal. This sample meal is kept under refrigeration for 24 hours so that it will be available for study in the event that the pilot develops a gastrointestinal illness during this period or subsequently. An effort is also made to assure that several people eat each meal so that an epidemiological study can be facilitated if necessary. The menu for these meals was provided by Miss Beatrice Finklestein of the Aerospace Medical Laboratory, Aeronautical Systems Division, U.S. Air Force Systems Command. The diet is tasty and palatable as is shown in table 5–I which gives a typical day's menu. It has caused no gastrointestinal upsets and is well tolerated by all persons who have consumed it. In order to assure that it would be well tolerated, all of the Mercury astronauts consumed this diet for a 3-day period during one of their visits to Wright-Patterson Air Force Base in one of the early phases of their training program. The use of a separate feeding facility provides the ability to control strictly the sanitation of food preparation during this preflight period. Such control could not as easily be exercised if meals were taken in a community cafeteria.

During this 3-day period before the launch day, the pilot lives in the Crew Quarters of Hangar "S" which is located in the industrial complex of Cape Canaveral. Here he is provided with a comfortable bed, pleasant surroundings, television, radio, reading materials and, above all, privacy. In addition to protection from the curious-minded public, the establishment of the pilot and the backup pilot in the Crew Quarters also provides a modicum of isolation from carriers of infectious disease organisms. This isolation is by no means complete and it is not intended to be. An effort is made to provide isolation from new arrivals in the community, however. It is felt that a certain amount of natural immunity has been acquired by the pilots in their day-to-day contacts with their associates at the launch site. Contact with visitors from different sections of the country might, however, introduce a strain to which no immunity had been acquired. Consideration was given at one time to the use of strict isolation techniques during this preparation period, but this

thought was abandoned because of its impracticality. The pilot plays a vital role in the preparations for his own flight. In order to be effective, a period of strict isolation would have to last for about 2 weeks; thus, the services of these important individuals would be unavailable for that period. Further, it was felt that a 2-week period of strict isolation would constitute a psychological burden which could not be justified by the results obtained. As mentioned previously, the pilot and his colleagues play a vital role in the preparation of the spacecraft and its launch vehicle for the flight. This period begins about 2 weeks prior to launch and continues up until the day before the launch. During this period of time, the pilot, on occasions, must don his full pressure suit and occupy the role of "capsule observer" during the course of certain checkout procedures. Advantage is taken of these exercises to perform launch rehearsals of varying degrees of sophistication. The most complete of these exercises occurs during the simulated flight which takes place 2 or 3 days prior to the launch. This dress rehearsal duplicates the launch countdown in event time and in elapsed time, but it occurs at a more convenient hour of the day. It not only enables those responsible for the readiness of the spacecraft and the launch vehicle to assure themselves of the status of these components, but it also allows those directly concerned with the preparation and insertion of the pilot to assure themselves of their own state of readiness. Finally, these exercises provide a certain degree of assurance and familiarity for the pilot himself.

On the evening before the flight, the pilot is encouraged to retire at an early hour, but he is not required to do so. The pilot of MR–3 spacecraft retired at 10:15 p.m. e.s.t., and the pilot of MR–4 spacecraft retired at 9:00 p.m. e.s.t. In both cases the pilots fell asleep shortly after retiring without benefit of sedatives or drugs of any kind. Their sleep was sound, and insofar as they could remember, was dreamless. The medical countdown for MR–4 flight called for awakening the pilot at 1:10 a.m. e.s.t. (table 5–II). This time was 65 minutes later than the wake-up time called for in the MR–3 countdown. Time was saved here by allowing the pilot to shave and bathe before retiring instead of after awakening in the morning. Another 15 minutes was saved by performing the final operational briefing in the transfer van on the way to the launch pad, rather than after arrival as was done in MR–3 flight. When they were awakened on the morning of the launch, both pilots appeared to have been sleeping soundly. There was no startle reaction on awakening, and the immediate postwaking state was characterized by eager anticipation and curiosity as to the progress of the countdown. After awakening, the pilots performed their morning ablutions and consumed a high protein breakfast consisting of fruit, steak, eggs, juice, and milk. No coffee was permitted during the 24-hour period preceding the flight because of its tendency to inhibit sleep. No coffee was permitted for breakfast on launch morning because of its diuretic properties.

After breakfast, the pilots donned bathrobes and were taken into the physical examination room where the preflight physical was performed. This examination is distinct from that conducted for the purpose of collecting background scientific data, which was performed by several examiners 2 to 3 days prior to the flight. This early examination is reported in paper 3 of the present volume and in reference 1. The physical examination performed on the morning of the flight was designed to ascertain the pilot's fitness to perform his mission. It was designed to discover any acute illness or infirmity which might contraindicate the flight.

These examinations failed to reveal anything of significance. The physiological bradycardia (pulse rate 60 to 70) and normotensive (blood pressure 110/70) state both give some indication of the calm reserved air of confidence which typifies both of these pilots. It is important to emphasize at this point that no medication of any kind was consumed by either of these pilots during the several days preceding the launch. Following the preflight physical examination, each of the pilots was given a short battery of psychological tests. In the case of the MR–4 pilot, it was possible to provide a short interview by a psychiatrist. Both the testing and the interview were part of the medical investigative program and are reported in paper 3 of the present volume and reference 1. Suffice it to say at this point that no abnormalities were detected.

The next step in the preparatory procedures was the application of the biological sensor harness (figs. 5–1 and 5–2). This harness is described in detail in reference 2. The only difference between the sensors used in MR–3 and MR–4 flights was an alteration of the respiration sensor housing for the MR–4 flight to accommodate the microphone of different configuration used in the later flight. The surface of the electrode next to the skin is prepared with an adhesive material identical to that found on conventional adhesive tape (elastoplast adhe-

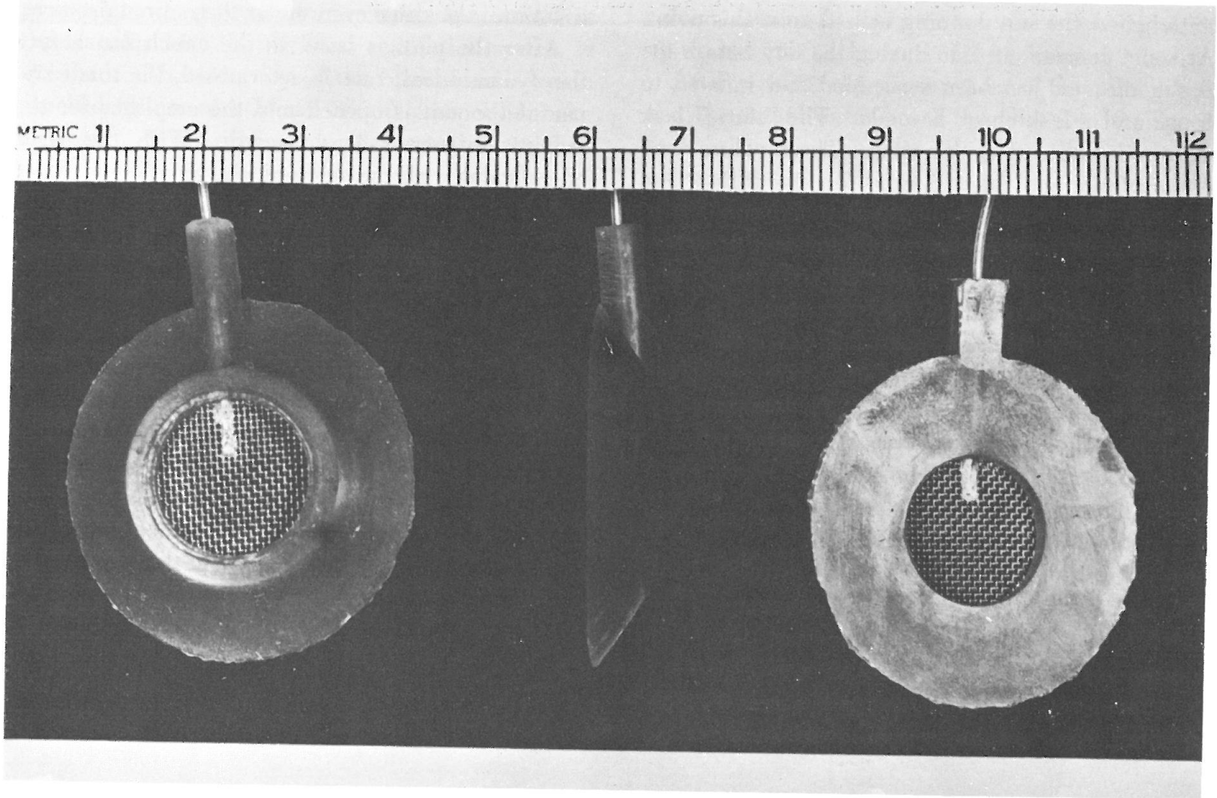

FIGURE 5–1. Three views of a typical electrocardiograph floating electrode as used in Project Mercury. The surface of the electrode applied to the skin (right) is first painted with adhesive and then filled with bentonite paste.

sive). This preparation must be done at least 15 minutes in advance since the solvent for the adhesive is irritating to the skin and must be given ample opportunity to evaporate before the sensor is applied. The dermal surface of this electrode is first filled with bentonite paste and the electrode is applied directly to the skin. The skin is first prepared by clipping the hair where necessary and by cleansing with surgical detergent (FSN 6505–116–1740). The sensor locations have been previously marked on all Mercury pilots by the use of a tiny (about 2 millimeters in diameter) tattooed dot at each of the four electrode sites. After the sensor is applied to the skin, the uppermost surface of the screen is covered with the bentonite paste and a small square of electrician's plastic tape is applied over the opening in the disk. The entire electrode is then covered with a square of moleskin adhesive tape. This assembly becomes, then, a floating electrode. The electrician's tape serves to retard somewhat the evaporation of water from the bentonite paste.

The deep body temperature probe (fig. 5–2) is simply a flexible rubber-covered thermistor. Since it is difficult, if not impossible, to sterilize this probe without causing deterioration of the device, each pilot is provided with his own personal sensor harness. This same harness is used in all practice exercises in which the individual participates. It is simply washed with surgical detergent after each use.

After the harness is applied, the integrity of the sensors is checked by the use of a modified Dallon Cardioscope (fig. 5–3). With this device, both electrocardiographic leads can be displayed on the oscilloscope, and the amplitude of the QRS (Q-wave, R–wave, S–wave) complex can be measured roughly by comparing it with a standard 1-millivolt current. The integrity of the respiration sensor can also be demonstrated by displaying the trace on the oscilloscope. No effort is made to calibrate the respiration sensor at this time. The temperature probe is also checked by use of a Wheatstone bridge.

After the sensors have been applied, the pilot moves to the pressure-suit room where he dons his suit. Since the most uncomfortable period of the countdown is that time spent in the suit, a check is made with the blockhouse to determine the status of the count. If there has been a delay or if one is

anticipated, the suit donning is held up at this point. At some convenient time during the day before the flight, the suit has been assembled and inflated to 5 psi, and a leak check is made. The "static" leak rate is determined at this time. These values were 190 cc/min and 140 cc/min for the MR–3 and MR–4 flights, respectively. After the pilot has donned his suit, he is placed in a couch in the pressure-suit room and the suit is again inflated to 5 psi. The ventilation flow is then turned off and a "dynamic" leak rate is obtained by reference to the flow of oxygen necessary to maintain this pressure. The dynamic leak rate for the MR–3 flight was 400 cc/min; for the MR–4, it was 175 cc/min. The term "leak rate" in this dynamic situation is used rather loosely since it encompasses not only the actual leak rate of the suit but also the metabolic use of oxygen. Exact measurement of this rate is further complicated by the presence of a breathing occupant of the suit; changes in the occupant's volume occasioned by respiratory movements are reflected as changes in the flow rate, but a rough estimation is possible even under these circumstances.

After the pilot is laced in the couch but before the dynamic leak rate is determined, the torso zipper of the suit is opened and the amplifier for the respiration sensor is delivered. With the visor closed, and with the microphone positioned as for flight, the amplifier is adjusted to provide a signal strong enough to be easily observed but not so strong as to overload the spacecraft telemetry equipment. Once the dynamic leak rate has been determined, the suit is not again disturbed except to open the helmet visor. No zippers are permitted to be loosened from that time on. Upon completion of the suit donning procedure, the pilot returns to the examination room where the biosensors are again checked on the oscilloscope. This would detect any disturbance created by the donning of the suit, and permit it to be corrected at this point rather than later.

If the medical count and the main countdown are still in agreement, a portable ventilating unit is attached to the suit and the pilot and insertion team

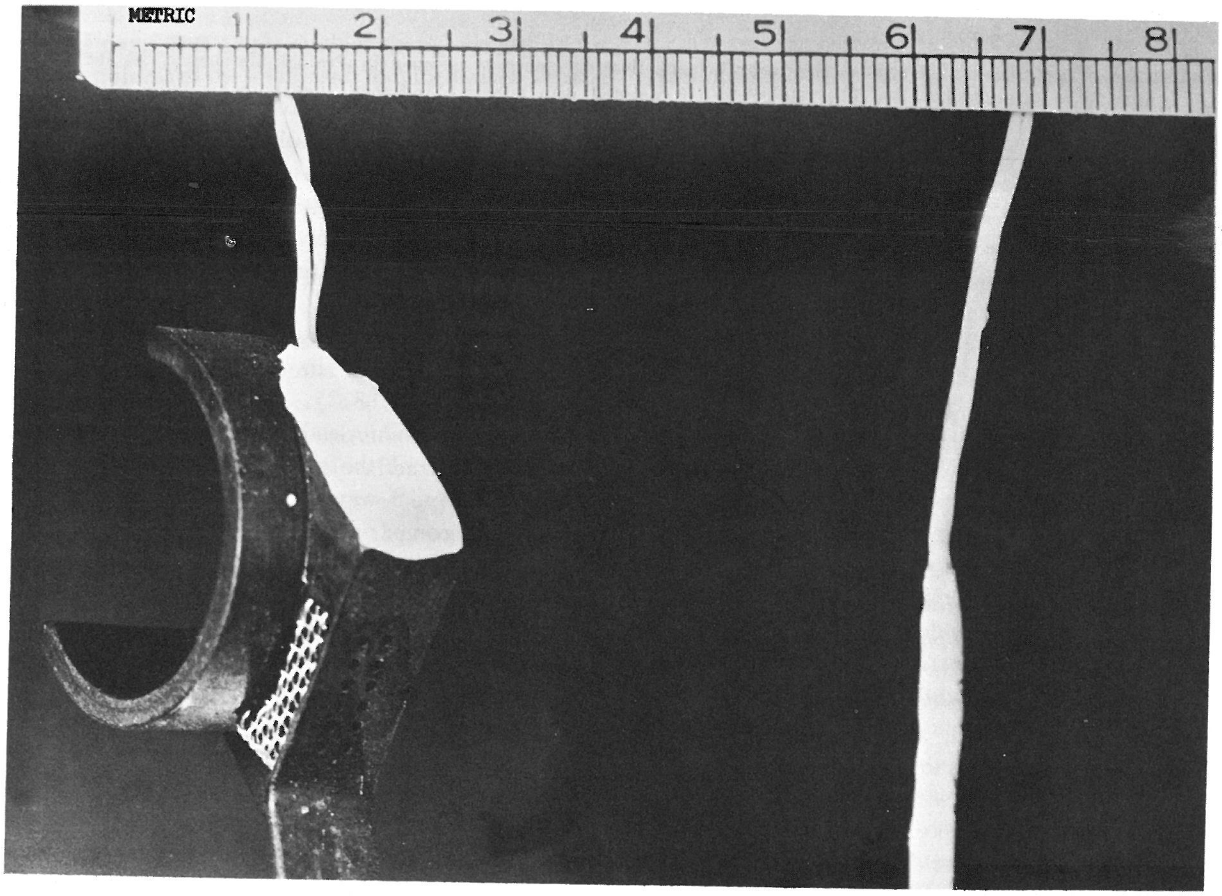

FIGURE 5–2. Respiration sensor (left) and deep body temperature probe (right).

proceed to the transfer van. Upon his arrival at the transfer van, the onboard ventilation system is attached. The integrity of the biosensors is again checked by use of a Model 350, 8-channel Sanborn recorder. The Sanborn recorder remains attached to the pilot from this point on, and a continuous recording of the measured biological functions is started. A sample record taken while the van was in motion is shown in figure 5–4.

Upon arrival at the launch site, two final strips of record are obtained from the Sanborn recorder and delivered to the medical monitors at the blockhouse and at the Mercury Control Center. Both of these records contain a 1-millivolt standardization pulse, and are utilized by the monitors to compare with their records as obtained from the spacecraft. When notified to do so by the blockhouse, the portable ventilating unit is reattached. The pilot, flight surgeon, pressure-suit technician, and a pilot observer (astronaut) leave the transfer van and proceed up the elevator to the level of the spacecraft.

At this point, the preparation of the pilot ceases and the actual insertion of the pilot into the spacecraft commences. After the pilot climbs into the spacecraft and positions himself in the couch, the pressure-suit technician attaches the ventilation hoses, the communication line, the biosensor leads, and the helmet visor seal hose, and finally, he attaches the restraint harness in position but only fastens it loosely. At this point, the suit and environmental control system is purged with 100-percent oxygen until such a time as analysis of the gas in the system shows that the oxygen concentration exceeds 95 percent. When the purge of the suit system is completed, the pressure-suit technician tightens the restraint harness; the flight surgeon makes a final inspection of the interior of the spacecraft and of the pilot, and the hatch installation commences. During

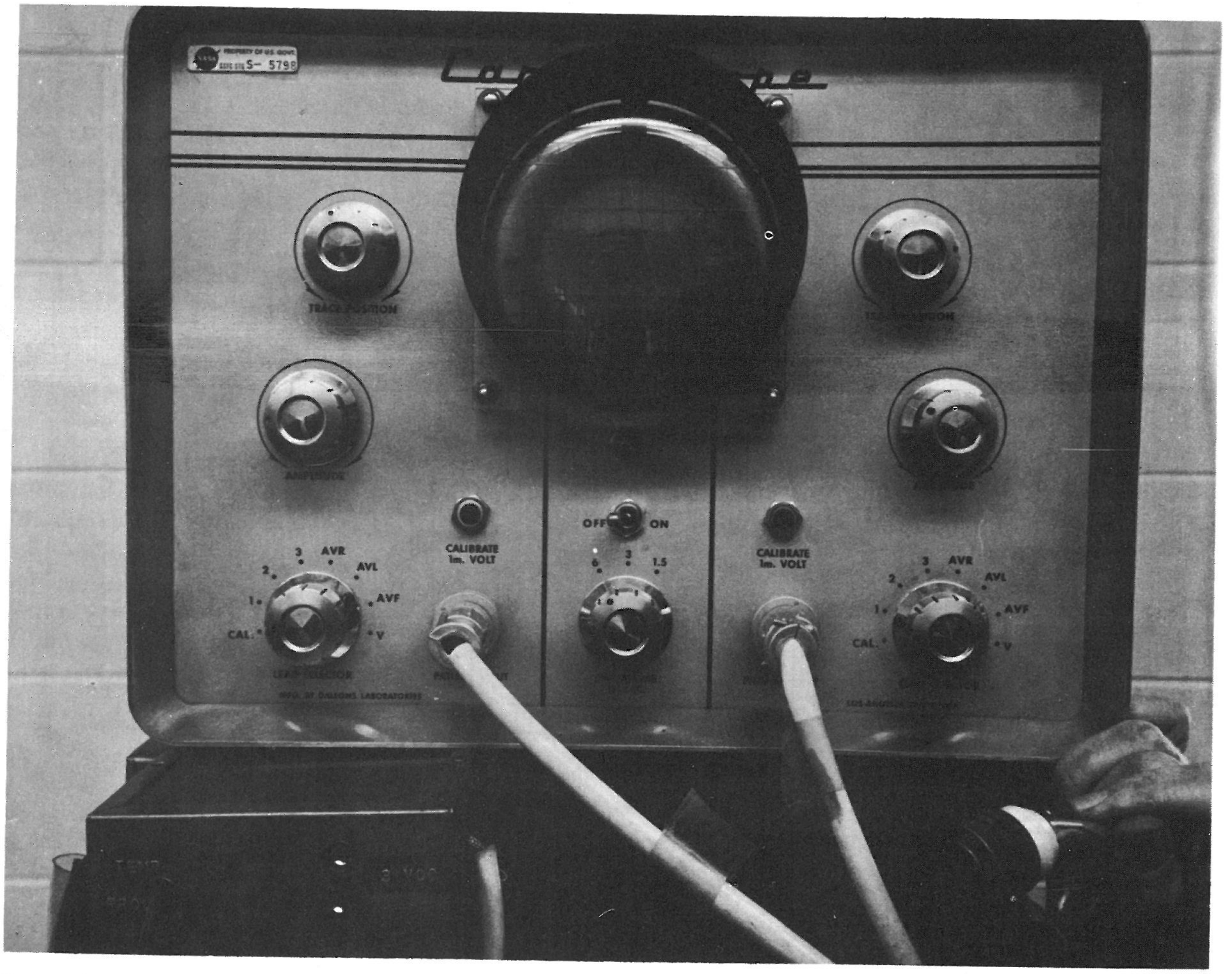

FIGURE 5–3. Cardioscope used to check out the biosensor harness. The lead into the suit is shown on the lower right, and the switching box to display respiration and temperature is shown on the lower left.

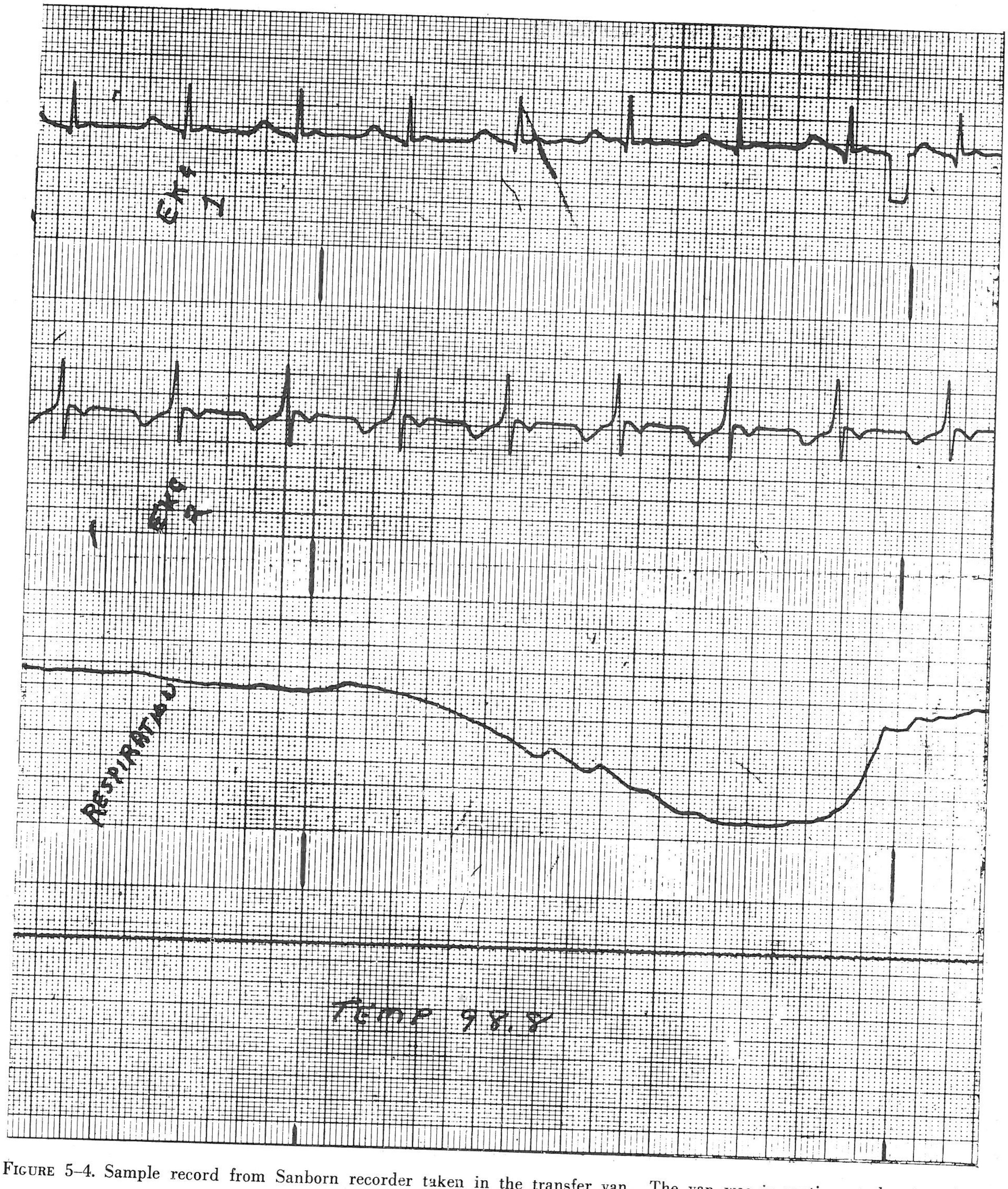

FIGURE 5–4. Sample record from Sanborn recorder taken in the transfer van. The van was in motion at the time this recording was made.

the insertion procedures, it is the flight surgeon's duty to monitor the suit purge procedure and to stand by to assist the pressure-suit technician or the pilot in any way he can. The final inspection of the pilot by the flight surgeon gives some indication of the pilot's emotional state at the last possible opportunity. The flight surgeon during this period is in continuous communication with the blockhouse surgeon and is capable of taking certain steps to analyze the cause of biosensor malfunction, should it occur. No such malfunctions occurred during the course of these two flights. After hatch installation is completed, the flight surgeon is released and proceeds to the forward medical station where he joins the point team of the land recovery forces.

Debriefing

After a successful launch, the flight surgeon leaves his position on the point team and proceeds immediately to the Mercury Control Center. Here he follows the progress of the recovery operations until it is clear where his services will be needed next. In the event the pilot is injured or is ill, the flight surgeon is taken by air to the aircraft carrier in the recovery area. If it is clear that the pilot is uninjured, as was true for MR–3 and MR–4 flights, the flight surgeon joins the debriefing team and is flown to the medical care and debriefing site at Grand Bahama Island, British West Indies. During this time, the pilot is undergoing a preliminary physical examination and debriefing aboard the carrier. In both of the flights under discussion, the debriefing team arrived at Grand Bahama Island about 30 minutes before the pilot who was flown there from the carrier. The debriefing site is a two-room prefabricated building with an adjacent heliport. The heliport is provided in the event it is more convenient, or is necessary by virtue of his physical status, to carry the pilot from the surface vessel to the debriefing site by helicopter.

Immediately upon their arrival at Grand Bahama Island, the pilots were taken to the debriefing building where the flight surgeon performed a careful physical examination. Here again, the purpose of this examination was not so much to collect scientific material as to assure that the pilot was uninjured and in good health. When this preliminary examination had been completed, the pilots were examined by a surgeon. No evidence of injury was found by this second examiner. Next, an internist examined the pilots. Laboratory specimens (blood and urine) were obtained and the pilots were examined by an ophthalmologist, a neurologist, and a psychiatrist. Chest X-rays (anteroposterior and right lateral) were taken. The results of all of these examinations were, in the main, negative and have been reported in paper 3 of the present volume and reference 1. Upon completion of the physical examination, the pilots were turned over to the engineering debriefing team.

The original plan for the pilot's postrecovery activities permitted him to remain at Grand Bahama Island for 48 hours after his arrival. This period was believed to be necessary to permit full and adequate recovery from the effects of the flight. In the case of the MR–3 flight, it was possible for the pilot to remain for 72 hours. The last day of this period was devoted to complete rest and relaxation. The additional 24-hour period was occasioned by the scheduling of the postflight press conference and public welcome in Washington, D.C. It was quite apparent that the postflight rest period was beneficial to the pilot. There is no objective measurement of this, but the day-to-day observations of the pilot showed him to be benefited by this relative isolation. In the case of the MR–4 flight, the pilot seemed to be recovering rapidly from the fatiguing effects of his flight and the postflight water-survival experience. His fatigue was more evident when seen 12 hours after his arrival at Grand Bahama Island than that observed in the pilot of the MR–3 flight when seen at the same time. On the following day, however, the MR–4 pilot seemed to be at about the same level of recovery as had been observed in the MR–3 pilot. For this reason, it was decided to permit the pilot of the MR–4 flight to return to Cocoa Beach, Fla., for a press conference at a time some 18 to 20 hours before that called for in the original plan. No evident permanent effects of this early return can be described, and the pilot performed well in his public appearances; but his fatigue state was much longer in dissipating as he was seen in the days subsequent to the flight. Again, this slower recovery cannot be demonstrated with objective findings, and must be accepted only as a clinical observation of the writer.

Concluding Remarks

The flight surgeon's activities and duties in support of two manned suborbital flights have been described and certain observations of the flight surgeon have been recorded. In summary, it is important to point out three items.

(1) During the 12-hour period preceding the launch, it is vital that the preparation of the pilot follow the countdown with clocklike precision. This precision becomes more urgent as the time approaches for insertion of the pilot into the spacecraft. In order to accomplish this precision, it is necessary to practice the preparation procedures time and time again. Time-motion studies are necessary. In the training program for the Mercury flights, each insertion of an astronaut into the centrifuge was performed just as if it were a real launch. At times during the checkout of the spacecraft, it was necessary to insert an astronaut into the spacecraft in an altitude chamber. Each of these events was conducted as for a launch. Even with these many opportunities to practice and perfect techniques, some changes were made after the MR–3 flight for the MR–4 flight. The fact that no delays were occasioned by the preparation procedures attests to the value of these repeated practice sessions.

(2) Very early in the planning for manned space flights, it was decided to train a backup man for each position in the medical support complex. A backup astronaut was always available; a backup flight surgeon was trained; and even a backup driver for the transfer van was available. These backup men not only provided substitutes of ready accessibility, but also permitted each person involved to get some rest on occasion. The primary individual was then capable of performing his task in an alert and conscientious manner on the actual day of the launch.

(3) In future manned flights, the planned 48-hour minimum debriefing period should be observed and even extended to include a 24-hour period of complete rest if indicated by the stresses experienced during the flight.

References

1. Jackson, C. B., Douglas, William K., et al.: *Results of Preflight and Postflight Medical Examinations.* Proc. Conf. on Results of the First U.S. Manned Suborbital Space Flight, NASA, Nat. Inst. Health, and Nat. Acad. Sci., June 6, 1961, pp. 31–36.
2. Henry, James P., and Wheelwright, Charles D.: *Biomedical Instrumentation in MR–3 Flight.* Proc. Conf. on Results of the First U.S. Manned Suborbital Space Flight, NASA, Nat. Inst. Health, and Nat. Acad. Sci., June 6, 1961, pp. 37–43.

Table 5–I.—*Sample Low-Residue Menu*

[Third day prior to space flight]

Breakfast:	
Orange juice	4 ounces
Cream of wheat	½ cup, cooked
Cinnamon or nutmeg	Few grains
Scrambled eggs	2
Crisp Canadian bacon	2 to 3 slices
Toast (white bread)	1 to 2 slices
Butter	1 teaspoon
Strawberry jelly	1 tablespoon
Coffee with sugar	No limit
Lunch:	
Chicken and rice soup	1 cup
Hamburger patty	3 to 4 ounces
Baked potato (without skin)	1 medium
Cottage cheese	2 rounded tablespoons
Bread (white)	1 to 2 slices
Butter	1 teaspoon
Sliced peaches (canned)	½ cup
Coffee or tea with sugar	No limit
Dinner:	
Tomato juice	4 ounces
Baked chicken (white meat)	4 ounces
Steamed rice	1 cup
Pureed peas	½ cup
Melba toast	1 to 2 slices
Butter	1 teaspoon
Lemon sherbet	¾ cup
Sugar cookies	2 to 3
Coffee or tea with sugar	No limit

TABLE 5-II.—*A Comparison of the Medical Countdown of MR-3 and MR-4 Flights*

Event	MR-3 flight		MR-4 flight	
	T—time, min ([1])	a.m. e.s.t. ([2])	T—time, min ([1])	a.m. e.s.t. ([2])
Awaken	−355	1:07	−290	1:10
Breakfast	−310	1:45	−275	1:30
Physical examination	−280	2:27	−245	1:55
Sensor application	−250	2:48	−215	2:15
Suit donning	−240	3:07	−205	2:55
Pressure check	−210	3:30	−175	3:13
Enter transportation van	−185	4:09	−150	3:28
Arrival at launch pad	−155	4:31	−125	3:54
Briefing	−155	4:31	Omitted	Omitted
Ascend gantry	−130	5:15	−125	3:55
Begin insertion	−118	5:21	−122	4:00
Launch	0	9:34:13	0	7:20:36

[1] Planned time during countdown according to the launch document.
[2] Actual time event occurred.

6. RESULTS OF INFLIGHT PILOT PERFORMANCE STUDIES FOR THE MR–4 FLIGHT

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Introduction

This paper presents a second report on the ability of the pilot to operate the space vehicle and perform all associated space-flight functions during Mercury flights. As with the previous paper, the analysis is directed toward establishing the capability of the man to perform in the weightless environment of space with essentially the same proficiency which he demonstrates under the more normal terrestrial conditions. The results of the analysis of the MR–3 flight indicated that the pilot was able to perform the space-flight functions, not only within the tolerances required for the successful completion of the mission, but within the performance levels demonstrated in fixed-base trainers on the ground under essentially optimal environmental conditions. From the first manned Mercury-Redstone flight, it was concluded that the performance data were essentially in keeping with the previous experience with manned aircraft flying zero-g trajectories. That is, the pilot was able to operate the space vehicle and perform other flight functions while exposed to the unusual environmental conditions of space, including a 5-minute period of weightlessness, without a detectable reduction in performance efficiency. As in the MR–3 flight, the astronaut's communications to the ground provide one source of data, while the telemetered records of vehicle attitude under manual control provide a second source, and a third source is the narrative description of the activities and events given by the pilot during the postflight debriefing. Not available for this report are the onboard pictures of the astronaut, since the film was lost with the spacecraft. This paper attempts to evaluate the performance of the pilot on the MR–4 mission, to compare the observations made by Astronaut Shepard and Astronaut Grissom of the earth and sky, as seen from space, and to compare their evaluations of the Mercury training devices.

The Astronaut's Flight Activities Plan

Three major differences between the MR–4 and MR–3 flights which are of significance to the astronaut's activities can be noted. First, spacecraft no. 11 (MR–4) differed from spacecraft no. 7 (MR–3) in that spacecraft no. 11 had available the centerline window which permits a view directly in front of the spacecraft. Through this window, the astronaut is able to see 33° in a vertical direction and approximately 30° horizontally. With the spacecraft in the orbit attitude, which is −34° with the small end down, two-thirds of the window is filled with the earth's surface and the upper one-third views space above the horizon. The size and location of this window provided an opportunity for better examination of the earth's surface and horizon than was possible through the 10-inch-diameter porthole available to Astronaut Shepard. The second variation from the MR–3 flight was in the checkout of the various reaction-control systems (RCS). During the MR–3 flight, Astronaut Shepard made use of the manual proportional and the fly-by-wire control systems, whereas during the MR–4 flight, Astronaut Grissom made use of the manual proportional system and the rate command system.

The third variation between the MR–3 and MR–4 flights was a slight reduction in the number of flight activities following the retrofire period on the MR–4 flight. The flight programs for Astronaut Shepard and Astronaut Grissom are compared in figure 6–1. Each begins with essentially the same launch period during which the astronaut monitors the sequential events and reports the status of the onboard systems approximately every 30 seconds. In both flights, the turnaround maneuver was performed on the autopilot with the astronaut monitoring the autopilot action. Immediately after the turnaround, both Astronaut Shepard and Astronaut Grissom selected the

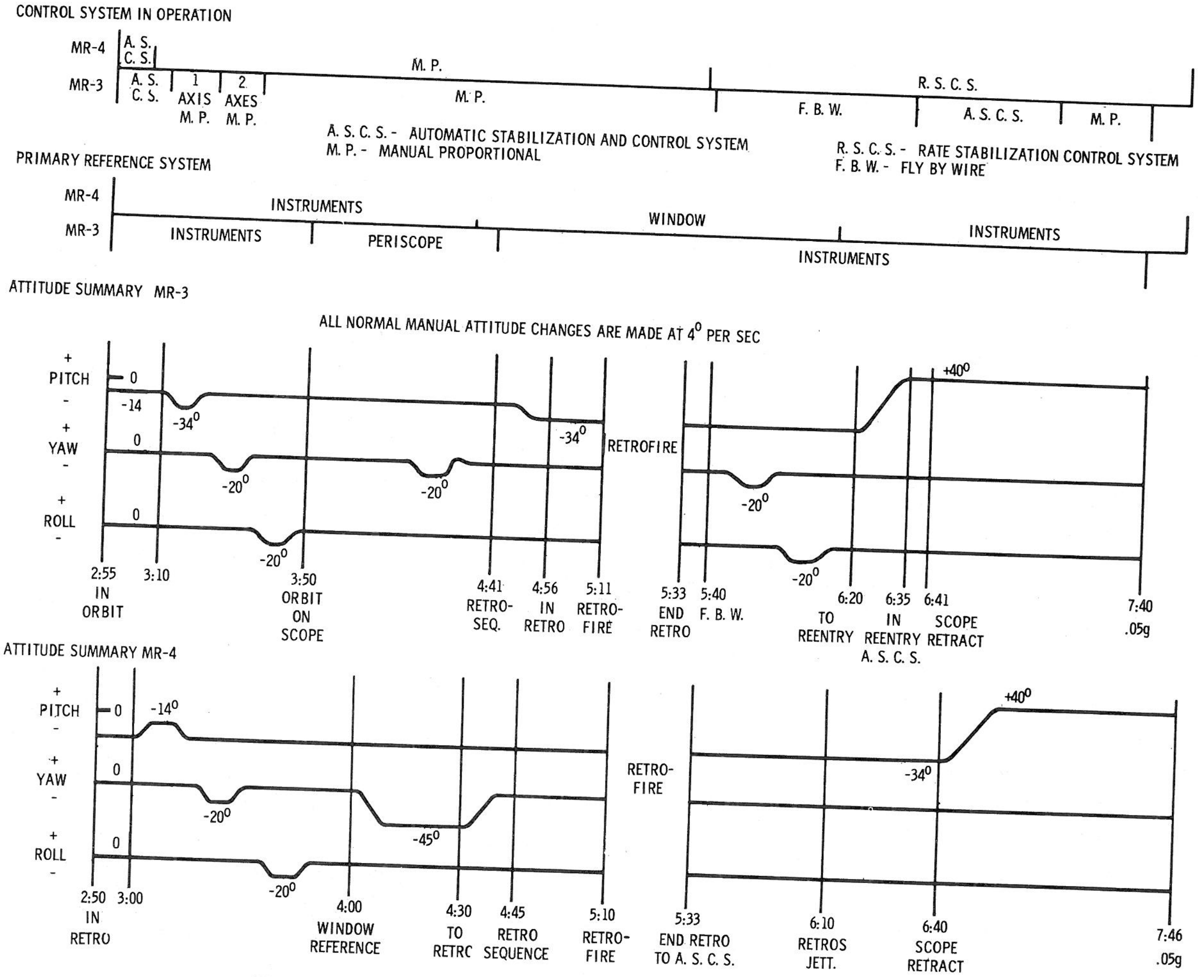

FIGURE 6–1. Manual control summary for the MR–3 and MR–4 flights.

manual proportional control mode and attempted to make a series of maneuvers: one each in pitch, yaw, and roll using the spacecraft attitude and rate indicator as a reference. After these three basic maneuvers, the astronaut shifted to an external reference. During this period, Shepard used the periscope, whereas Grissom used the window. Each reported what could be seen through these observation systems. In addition, Grissom made a 60° left yaw manuever to the south.

Following this period on external reference, the retrofire maneuver started. This maneuver commenced with the countdown from the ground to the retrosequence. From the retrosequence to the start of retrofire, there is a 30-second period during which the astronaut brings the vehicle into the proper attitude for retrofiring. This is followed by a retrorocket firing period of approximately 20 seconds. Both Astronaut Grissom and Astronaut Shepard controlled the spacecraft attitude during this period using the instrument reference and the manual proportional control system.

Following retrofire, Astronaut Shepard attempted to do a series of maneuvers using the fly-by-wire system and the spacecraft instruments as a reference. This series of maneuvers was omitted for Astronaut Grissom's flight; instead, he switched to the rate command system and returned to the window reference for further external observations. During this period both Astronaut Shepard and Astronaut Grissom made a check of the HF communications radio system.

The next mission phase began at approximately T+6 minutes 40 seconds with the astronaut pitching up to reentry attitude. At this point, both Astronaut Shepard and Astronaut Grissom looked for stars, Shepard using the small porthole on his left and Grissom using the large centerline window. Neither astronaut was able to see any stars at this time.

Following this period of observation, the reentry began. Astronaut Shepard used the manual proportional control mode and rate instruments to control the reentry; whereas Grissom used the rate command control mode and rate instruments during this period. Since the reentry oscillations caused no discomfort or concern, little control was exercised by either astronaut.

Although Astronaut Grissom had been relieved of some of the attitude maneuvers that were required of Astronaut Shepard between the retrofire and the reentry period, his program was still a full one. These full programs resulted from the decision to make maximum use of the short weightless flight time available during the Redstone missions.

Attitude Control

The curves of figure 6–2 are the attitudes of pitch, yaw, and roll maintained by Astronaut Grissom throughout the flight. The shaded area in the background indicates the envelope of attitudes maintained during 10 Mercury procedures trainer runs the week prior to the MR–4 flight. As described in paper 2 of this volume, there was a malfunction of the manual proportional control system. This malfunction resulted in Astronaut Grissom's receiving less than the normal amount of thrust per control stick deflection. This anomaly in the performance of the manual proportional control system resulted in the first three maneuvers being performed somewhat differently from those on the trainer, though generally still within the envelope of the trainer runs. The pitch and yaw maneuvers overshot the 20° desired attitude, and the time to make each maneuver was somewhat increased. This longer maneuvering time in pitch and yaw, plus the time required to remove residual roll rates, prevented the attempt to make the roll maneuver. It is interesting to note that Astronaut Shepard on his flight was also pressed for time at this point and cut the roll maneuver short, rolling only 12° instead of 20°. Following these three attitude maneuvers, Astronaut Grissom made a left yaw maneuver of approximately 60°, using the manual proportional control mode and window reference. This maneuver was performed approximately as it was during the trainer sessions.

Both Grissom and Shepard maintained the attitude of the spacecraft manually during the firing of the retrorockets. During the critical period of approximately 20 seconds in which the retrorockets were firing, the attitudes were held very close to the proper retroattitude of 0° in roll and yaw and −34° in pitch. The accuracy with which Astronaut Grissom held these attitudes is shown by the curves in figure 6–3 with the envelope of trainer runs in the background. The permissible attitude limits inside of which the retrorockets can be fired are shown as the extents of the ordinate scale labels. Outside of these limits, the retrorocket firing sequence would be interrupted until all the attitudes returned to within the permissible limits. Attitude control performance during this period was well within the limits required for a safe landing from orbit in the planned recovery area. The pilot stated during the debriefing that controlling attitude during the retrofire for the MR–4 flight appeared to be about equal in difficulty to the procedures trainer. For the training runs, using the fixed-base trainer, retrorocket-misalinement levels were selected which simulated misalinement torques equal to approximately 60 percent of the available reaction control system control torque. Since it is not possible to measure the retrorocket-

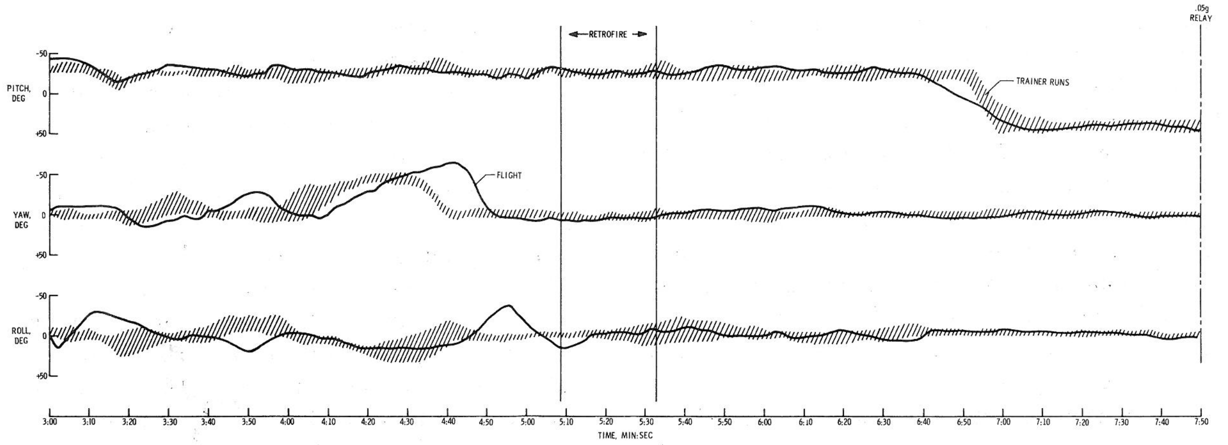

FIGURE 6–2. The MR–4 flight attitudes with four trainer runs in the background.

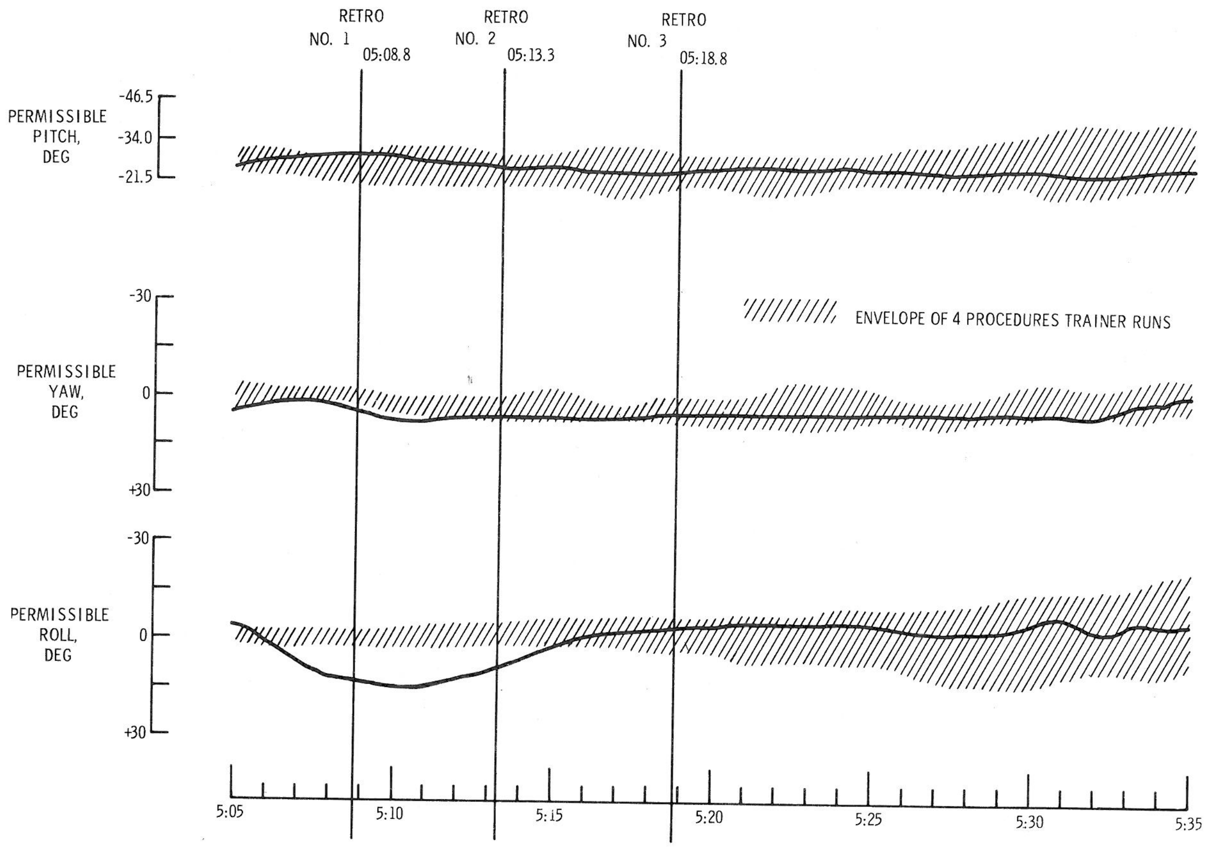

FIGURE 6–3. Attitude control during MR–4 retrofire period.

misalinement torques actually encountered during the flight, the performance of the system and of the pilot cannot be evaluated in detail. In addition, the pilot's assessment of the retrofire difficulty level may be a result of reduced effectiveness of the manual proportional control system, rather than large retro-rocket-mislinement torque levels.

Following the retrofire period, Astronaut Grissom shifted to the rate command control and maintained the spacecraft attitude at $-34°$ pitch and $0°$ roll and yaw until $T+6$ minutes 34 seconds, at which time he pitched to the proper reentry attitude. The attitude control during this period is well within the envelope demonstrated during the fixed-base trainer runs. During the rentry, the pilot made use of the rate command system, which provides automatic rate damping to ± 3 deg/sec if the stick is maintained in the center position. This system appeared to work well and no control action was required of the pilot to damp rates.

In summary, the pilot was able to accomplish the majority of the planned attitude maneuvers, despite the malfunction of the control system. This fact, together with the excellent control performance during the critical retrofire portion of the mission, provides an indication that pilot's control performance was not degraded during the approximately 5 minutes of weightless flight.

Flight Voice Communications

Ninety-four voice communications were made by Astronaut Grissom between lift-off and impact. (See appendix.) As in Astronaut Shepard's flight, these voice communications provide an indication of how well the astronaut was able to keep up with the mission events, how accurately he was able to read his cockpit instruments, and how well he was able to respond to novel and unusual events during the flight. In general, the astronaut made all of the normal reports during the launch and reentry at the times appropriate to the event. His instrument readings relayed to the ground showed general agreement with telemetered data. In addition to the standard voice reports of spacecraft events and in-

strument readings, Astronaut Grissom made a number of unscheduled reports of the unique events of the flight. He reported and described the unique view through the centerline window and the problem with the attitude control system.

Pilot Observations

The major sensory observations made by the pilots during the MR–3 and MR–4 flights were those of vision, auditory phenomena, vibration, angular acceleration, linear acceleration, weightlessness, and general orientation.

Vision

On the MR–4 flight, Astronaut Grissom used the centerline window for the bulk of his external observations, whereas Astronaut Shepard primarily used the periscope. The major areas of observation are listed as follows:

Earth's surface.—Astronaut Grissom was hampered in his attempts to identify land areas due to extensive cloud coverage. He was, however, able to make some observations as evidenced by the following quotations from the postflight debriefing sessions: ". . . The Cape is the best reference I had. . . . I could pick out the Banana River and see the peninsula that runs on down south, and then on down the coast of Florida. I saw what must have been West Palm Beach . . . and it was a dark brown color and quite large. I never did see Cuba. High cirrus blotted out everything except an area from about Daytona Beach back inland to Orlando and Lakeland to Lake Okeechobee and down to the tip of Florida. Beyond this the Gulf of Mexico was visible."

Astronaut Shepard was less hampered by cloud formations during his flight. His observations through the periscope were reported as follows in the postflight debriefing sessions: ". . . The west coast of Florida and the Gulf coast were clear. I could see Lake Okeechobee. I could see the shoals in the vicinity of Bimini. I could see Andros Island . . . Tampa Bay. . . . There was an abrupt color change between the reefs, in the area of Bimini and the surrounding water."

Clouds.—Because of shortage of time and/or high cirrus clouds that obscured any underlying vertical cloud formations, neither Astronaut Shepard nor Astronaut Grissom was able to report cloud heights during the MR–3 and MR–4 flights.

Horizon.—Astronaut Grissom described the horizon as "very smooth as far as I could see . . . a blue band above the earth, then the dark sky. It is very vivid when you go from the blue to the dark. . . . The blue band appears about a quarter of an inch wide."

Astronaut Shepard viewed the horizon through the small 10-inch-diameter porthole. He described his view as follows: ". . . There was only one haze layer between the cloud cover and the deep blue. . . . It was a little hazy, or what looked like haze; so there was no real sharp definition between clouds, haze layer, or the horizon and sky."

Sky.—Astronaut Grissom reported that the sky was very black and that the transition from blue to black was very rapid during the launch phase.

Astronaut Shepard on the MR–3 flight had the impression that the sky was a very dark blue rather than black.

Stars.—The high contrast between the cabin interior light intensity and external areas for both suborbital flights made it very difficult for either pilot to locate stars. Astronaut Shephard did not see any stars during his flight. Astronaut Grissom was not able to locate any stars during the scheduled external observation period of his flight; however, he did locate what appeared to be a star late in the powered phase of the flight. Subsequent investigations indicate that he saw the planet Venus.

Sun.—The sun never posed a great problem for either of the astronauts during the suborbital missions. It entered the cabin either directly or reflected during both flights. Unlike Shepard, Astronaut Grissom did have some minor difficulties with sunlight. His statements were: "The sun was coming in bright at 0.05g and I think I would have missed it if I hadn't known that it was due and coming up. . . . I looked real close and I did see it. . . . It comes in pretty much as a shaft of light with everything else in the cockpit dark."

Use of earth reference for attitude control.—Both astronauts expressed confidence that it would be possible to determine rates and attitudes by the use of their respective available external reference devices. Astronaut Shepard said, "Qualitatively, I noticed nothing that would prevent it [periscope] from being a good backup for the instruments, for attitude reference and for control."

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ready yaw reference and then it [yaw rate] was quite apparent, and I could control on that basis."

Other visual phenomena.—Neither pilot was able to observe the launch vehicle at any time during the flights. At tower separation, the periscope has not as yet extended so Shepard was not able to observe the tower jettisoning. However, the centerline window provided Grissom with a direct view of this operation. His comment is as follows: "I didn't see any flame, but I could see it go and I could see it for a long time after it went. I could see the little tail-off and it occurred to me that it went slightly off to my right."

Both pilots were able to observe through the periscope some portions of the retropackage after it had been jettisoned. Astronaut Grissom's comment was: "Right after retrojettison, I saw something floating around. It actually looked like a retromotor at one time, and these floated by a couple of times."

Astronaut Shepard's comment was: "I heard the noise and saw a little bit of the debris. I saw one of the retropack's retaining straps."

During the reentry phase, Astronaut Grissom reported observing what he describes as shock waves. His report was: "I'm fairly certain it was shock waves off the shield of the capsule. It looked like smoke or contrail really, but I'm pretty certain it was shocks."

Drogue parachute deployment was observed by both pilots. Shepard observed this event through the periscope and Grissom through the centerline window. Astronaut Shepard reported: "The drogue [parachute] came out at the intended altitude and was clearly visible through the periscope."

Astronaut Grissom observed: "The drogue [parachute] came right out. I could see the canister go right on out and the drogue deploy."

Main parachute deployment was obvious to both pilots. Astronaut Grissom was afforded the best view of the parachute through the centerline window. Astronaut Grissom reported: "I could see the complete chute when it was in the reefed condition and after it opened I could see, out the window, 75 percent of the chute."

Astronaut Shepard's comment was: "Then at 10,000 feet, of course, the antenna canister went off, and you could see it come off and pull the main chute with it and then go off in the distance. You could see the chute in the reefed condition. Then it dereefed." When asked, "Did you see the chute at full inflation?" he replied, "Yes, I would say probably three-fifths of the chute area; over half, anyway."

Astronaut Grissom observed the reserve parachute canister in the water through the periscope after it had jettisoned.

Astronaut Grissom was not able to locate any of the recovery ships or search aircraft. Shepard was able to see the search aircraft in the recovery area. He reported during the debriefing, "I didn't see any airplanes out the 'scope until after I had hit, but I saw the choppers through the 'scope after impact."

Auditory Phenomena

The noise encountered by both pilots did not at any time reach a disturbing level. The major mechanical functions of the spacecraft were audible to both astronauts. Their reports of the various functions are as follows:

Shepard observed: "Sounds of the booster [launch vehicle], the pyros [pyrotechnics] firing, the escape tower jettisoning, and the retros firing could be heard. All these sounds were new; although none of them was realy loud enough to be upsetting, they were definitely noticeable. I remember thinking I did not hear the noise of the manual jets firing. I was aware of the posigrade firing and of just one general noise pulse."

Grissom reported: "At no time did we have any annoying sound level. You can hear the escape rocket fire, the posigrades, and you can hear the retrorockets fire and feel them. You can hear the pitch and yaw jets fire, and that's about it."

Both astronauts reported that they heard the retrorocket package jettison and heard the firing of the drogue-parachute mortar. However, only Shepard recalled hearing the antenna mortar firing.

Vibration

The vibrations encountered by Astronaut Grissom during the MR–4 flight were less than those experienced by Astronaut Shepard on the MR–3 flight. This was primarily a result of (1) an improved fairing between the spacecraft and the launch vehicle and (2) added sound attenuating material in the couch. Vibration was experienced only during the launch phase of both flights. The astronauts' reports of the vibrations encountered and their effects are as follows. Shepard's comments were: "From the period of about 45 to 50 seconds after lift-off and through about a minute and a half there was some vibration. I could feel vibrations building up, and the sound level came up a little bit until at one point, I'm not sure whether it was at max q [maximum dynamic pressure] or not, there was enough

vibration in the capsule [spacecraft] that there was a slightly fuzzy appearance of the instrument needles. Then, after we got through max q, everything smoothed out." The degradation of vision associated with this vibration was not serious.

Grissom observed: "I called out vibrations as soon as they started and they never did get very bad at all. I was able to see the instrument panel and see the instruments clearly all the time and to transmit quite clearly."

Angular Acceleration

Astronaut Grissom reported that he was able to discern angular accelerations during spacecraft turnaround and retrofire. He did not think that he could feel the accelerations produced in controlling the spacecraft:

Astronaut Shepard had much the same experience on the MR–3 flight. He was also able to feel the angular accelerations during periods when there were high torques acting on the spacecraft.

Linear Accelerations

Both pilots were aware of the linear accelerations connected with the main functions of the spacecraft, such as posigrade firing at spacecraft separation, retrorocket firing, reentry, drogue parachute deployment, main parachute deployment, and impact. In addition, Astronaut Grissom was able to identify the deployment of the landing bag. He stated, "I could feel it [the landing-bag deployment], but it was just a slight jar as the thing dropped down."

Astronaut Shepard stated that the landing-bag shock was so slight that he did not notice it.

Weightlessness

Both pilots experienced approximately the same sensations during the weightless phase of the flight. They both had to make a special effort to notice the weightless condition. Astronaut Shepard made these observations concerning his flight: "I said to myself, 'Well, OK, you've been weightless for a minute or two and somebody is going to ask you what it feels like.' . . . In other words, I wasn't disturbed at all by the fact that I was weightless. I noticed a little bit of dust flying around, and there was one washer over my left eye. . . . I was not uncomfortable and I didn't feel like my performance was degraded in any way. No problems at all."

Astronaut Grissom's primary cue to the weightless condition was also a visual one, as is indicated by his comments during the debriefing: ". . . At zero-g, everything is floating around. I could see washers and trash floating around. I had no other feeling of zero-g; in fact, I felt just about like I did at 1g on my back or sitting up."

General Orientation

Neither pilot experienced any unexpected disorientation. Astronaut Shepard, in fact, experienced no disorientation at any time as is indicated by his statements during the debriefing.

Astronaut Grissom, on the other hand, experienced a slight pitching forward sensation at launch-vehicle cutoff. His comment was: ". . . Right at BECO [booster-engine or launch-vehicle cutoff] when the tower went, I got a little tumbling sensation. I can't recall which way it was that I felt I tumbled, but I did get the same sort of feeling that we had on the centrifuge. There was a definite second of disorientation there. I knew what it was, so it didn't bother me." Most of the astronauts have experienced this sensation during this period on dynamic centrifuge simulations. Grissom further commented: "Prior to retrofire, I really felt that I was moving; I was going backwards. . . . When the retros fired, I had the impression I was very definitely going the other way."

Training Program Evaluation

The Mercury astronaut training program was described by Astronaut Slayton in the report on the Mercury-Redstone flight 3 (ref. 1). As a result of the two suborbital flights, a preliminary evaluation of some portions of the training program are possible. The pilots' comments on some of the more important phases of training are given in this section.

General Comments

Astronaut Shepard reported that he felt sufficiently trained for the mission. He felt that the training produced a ". . . feeling of self-confidence as well as the physical skills necessary to control the vehicle." He did not believe that any areas of training had been neglected. He reported, ". . . that as a result of the training program, at no time during the flight did I run into anything unexpected." With regard to items in the training program which might be omitted, Astronaut Shepard reported, "All the training devices and phases we experienced were valuable." However, since he felt that the physio-

logical symptoms associated with weightlessness and other space flight environmental conditions were not going to be a problem, he believed the time devoted to weightless flights and disorientation devices could be reduced.

Astronaut Grissom stated after the flight that he felt least well prepared in the recovery portion of the mission. He also felt that additional practice on the air-lubricated free-attitude trainer during the last 2 weeks prior to the mission would have been desirable. This simulator is at NASA-Langley Air Force Base, Va., and not available to the astronaut who must remain close to the launch site just prior to the flight. Astronaut Grissom also felt he should have had more time at the planetarium and for map study. Like Astronaut Shepard, he did not feel any of the training phases were unnecessary, but that the time on some trainers could be reduced.

Weightless Flying

Astronaut Shepard reported that, "... The weightless flying is valuable as a confidence-building maneuver." Astronaut Grissom agreed that the training was valuable and that he would not want to be without it. Both reported that the flights in the F-100 airplanes in which they experienced 1 minute of weightlessness, while strapped in the seat, were most similar to their Redstone-Mercury flight experiences. Shepard felt that the amount of weightless flying could have been reduced.

Fixed-Base Procedures Training

Both pilots felt this was a very valuable trainer, particularly when tied into the Mercury Control Center simulations. Astronaut Shepard made less use of the procedures trainer than he might otherwise have because of the difference in the panel arrangement between the trainer and the early model of the spacecraft which he flew. Shepard felt that the computer attitude simulation provided an accurate reproduction of the flight dynamics. Grissom was not able to make a good evaluation of this portion of the simulation due to the malfunction of the control system on his flight.

Shepard stressed the importance of accurate timing of events in the procedures trainer, noting that a small time inaccuracy had momentarily disturbed him during the flight. Grissom suggested that where possible, sound cues associated with mission events should be added to the simulation.

Air-Lubricated Free-Attitude Trainer

Both pilots felt that the air-lubricated free-attitude (ALFA) trainer, a moving-base trainer which provides angular-acceleration cues as well as a simulation of both the window and periscope views of the earth, was very good for developing skill in the attitude control task. It was more valuable to Grissom since the spacecraft he flew had the centerline window. The angular response of the ALFA trainer appeared to be accurate to Shepard and he felt that this trainer was a necessary addition to the fixed-base training. As already noted, Astronaut Grissom felt that more practice in the ALFA trainer with the pilot using the window reference would have been desirable. He felt that the horizon simulation which, at present, is only an illuminated band should be improved. Both pilots reported that the simulated periscope view employing a projected earth map was very valuable.

Centrifuge

Both pilots felt that the centrifuge provided valuable training for launch and reentry periods. Shepard reported that simulated accelerations of the centrifuge during retrofiring were far more jerky and upsetting than those occurring during the flight. ". . . which were very smooth." Grissom agreed that the flight accelerations were smoother; he felt that the centrifuge simulations were more difficult than the flight. The centrifuge had prepared him for a slight momentary vertigo sensation which he experienced just after cutoff of the launch-vehicle engine.

Participation in Spacecraft Checkout Activities at the Launch Site

Both pilots felt that this portion of their preparation was particularly essential. During this period, they were able to familiarize themselves with the unique features of the actual spacecraft they were to fly. Grissom summed up the value of this training as follows: "It is good to get into the flight capsule [spacecraft] a number of times; then on launch day, you have no feeling of sitting on top of a booster [launch vehicle] ready for launch. You feel as if you were back in the checkout hangar—this is home, the surroundings are familiar, you are at ease. You cannot achieve this feeling of familiarity in the procedures trainer because there are inevitably many small differences between the simulator and the capsule [spacecraft]."

APPENDIX

Air-Ground Communications for MR–4

The following table gives a verbatim transcription of the communications between the spacecraft and the ground during the MR–4 flight. The call signs listed in the second column identify different elements of the operation. The spacecraft is identified as "Bell 7" for Liberty Bell 7. The astronaut communicator in the Blockhouse is identified as "Stony." "Cap Com" is the astronaut communicator in the Mercury Control Center. "Chase" is an astronaut in an F–106 airplane. "ATS" stands for the "Atlantic Ocean Ship," a Mercury range station aboard a ship which had been moved in close to the landing area for this flight. "Hunt Club" is the designation given to the recovery helicopters. "Card File" is the designation of a radio-relay airplane which relayed the spacecraft communications to the Mercury Control Center.

Communication number	*Communicator*	*Time, min:sec*	*Transmission duration, sec*	*Communication*
	Stony	0:01	1	Lift-off.
1	Bell 7	0:03	4. 5	Ah, Roger. This is Liberty Bell 7. The clock is operating.
	Cap Com	0:08	3	Loud and clear, José, don't cry too much.
2	Bell 7	0:11	1. 5	Oke-doke.
		0:18	2. 5	OK, it's a nice ride up to now.
	Cap Com	0:20	1	Loud and clear.
3	Bell 7	0:21. 5	1. 5	Roger.
		0:28	8. 5	OK. The fuel is go; about 1½ g's; cabin pressure is just coming off the peg; the O_2 is go; we have 26 amps.
	Cap Com	0:36. 5	2. 5	Roger. Pitch [attitude] 88 [degrees], the trajectory is good.
4	Bell 7	0:39	2	Roger, looks good here.
	(1)	0:54	6. 5	OK, there. We're starting to pick up a little bit of the noise and vibration; not bad, though, at all. 50 secs., more vibration.
5	Bell 7	1:01.5	6. 5	OK. The fuel is go; 1½ g's; cabin is 8 [psi]; the O_2 is go; 27 amps.
		1:08.5	0. 5	And [Rest of communication not received.]
	Cap Com	1:09	1	Pitch is [Rest of communication not received.]
6	Bell 7	1:10	0. 5	4[g], 5[g] [Rest of communication not received.]
	Cap Com	1:11	2	Pitch [attitude] is 77 [degrees]; trajectory is go.
7	Bell 7	1:13	9. 5	Roger. Cabin pressure is still about 6 [psi] and dropping slightly. Looks like she's going to hold about 5.5 [psi].
8	Bell 7	1:23	0. 5	Eh [Rest of communication not received.]
	Cap Com	1:23.5	0. 5	Cabin [Rest of communication not received.]
9	Bell 7	1:24	1. 5	Believe me, O_2 is go.
	Cap Com	1:26	3	Cabin pressure holding 5.5 [psi].
10	Bell 7	1:29	1. 5	Roger, roger.
		1:31	15. 5	This is Liberty Bell 7. Fuel is go; 2½ g's; cabin pressure 5.5; O_2 is go; main [bus] 25 [volts], isolated—ah, isolated [bus] is 28 [volts]. We are go.
	Cap Com	1:46.5	3	Roger. Pitch [attitude] is 62 [degrees]; trajectory is go.
11	Bell 7	1:49.5	3	Roger. It looks good in here.
		1:56	18. 5	Everything is good; cabin pressure is holding; suit pressure is OK; 2 minutes and we got 4 g's; fuel is go; ah, feel the hand controller move just a hair there; cabin pressure is holding, O_2 is go; 25 amps.

[1] Communicator unidentified.

Communication number	Communicator	Time, min:sec	Transmission duration, sec	Communication
	Cap Com	2:15	1. 5	Roger, we have go here.
12	Bell 7	2:16.5	0. 05	And I see a star!
	Cap Com	2:17	1. 5	Stand by for cutoff.
13	Bell 7	2:23	2	There went the tower.
	Chase 1	2:24.5	1. 5	Roger, there went the tower, affirmative Chase.
14	Bell 7	2:26	4	Roger, squibs are off.
	Cap Com	2:31.5	0. 5	Roger.
15	Bell 7	2:33	9. 5	There went posigrades, capsule has separated. We are at zero g and turning around and the sun is really bright.
	Cap Com	2:42.5	4. 5	Roger, cap. sep. [capsule separation light] is green; turnaround has started, manual handle out.
16	Bell 7	2:47	13. 5	Oh boy! Manual handle is out; the sky is very black; the capsule is coming around into orbit attitude; the roll is a little bit slow.
	Cap Com	3:01	0. 5	Roger.
17	Bell 7	3:02	8. 0	I haven't seen a booster anyplace. OK, rate command is coming on. I'm in orbit attitude, I'm pitching up. OK, 40 [Rest of communication not received.] Wait, I've lost some roll here someplace.
	Cap Com	3:10.5	3. 5	Roger, rate command is coming on. You're trying manual pitch.
18	Bell 7	3:15.5	3	OK, I got roll back. OK, I'm at 24 [degrees] in pitch.
	Cap Com	3:20.5	4	Roger, your IP [impact point] is right on, Gus, right on.
19	Bell 7	3:24.5	3	OK. I'm having a little trouble with rate, ah, with the manual control.
	Cap Com	3:28	0. 5	Roger.
20	Bell 7	3:31	4	If I can get her stabilized here, all axes are working all right.
	Cap Com	3:36	3	Roger. Understand manual control is good.
21	Bell 7	3:40.5	3	Roger, it's—it's sort of sluggish, more than I expected.
22	Bell 7	3:45	1. 4	OK, I'm yawing.
	Cap Com	3:47.5	1. 5	Roger, yaw.
23	Bell 7	3:50	1	Left, ah.
24	Bell 7	3:51.5	4	OK, coming back in yaw. I'm a little bit late there.
	Cap Com	3:57.5	2	Roger. Reading you loud and clear, Gus.
25	Bell 7	3:59.5	2	Lot of stuff—there's a lot of stuff floating around up here.
26	Bell 7	4:02	12	OK, I'm going to skip the yaw [maneuver], ah, or [rather the] roll [maneuver] because I'm a little bit late and I'm going to try this rough yaw maneuver. About all I can really see is clouds. I haven't seen any land anyplace yet.
	Cap Com	4:15	3. 5	Roger, you're on the window. Are you trying a yaw maneuver?
27	Bell 7	4:18.5	5. 5	I'm trying the yaw maneuver and I'm on the window. It's such a fascinating view out the window you just can't help but look out that way.
	Cap Com	4:25	1. 5	I understand.
28	Bell 7	4:29.5		You su, ah, really. There I see the coast, I see.
	Cap Com	4:30.5	1. 5	4+30 [elapsed time since launch] Gus.
	(a)	4:33	4. 5	4+30 [elapsed time since launch] he's looking out the window, A–OK.
29	Bell 7	4:37.5	3. 5	I can see the coast but I can't identify anything.
	Cap Com	4:42	2	Roger, 4+30 [elapsed time since launch] Gus.
30	Bell 7	4:44	4	OK, let me get back here to retro attitude, retro sequence has started.
	Cap Com	4:48	3. 5	Roger, retro sequence has started. Go to retro attitude.
31	Bell 7	4:52	4	Right, we'll see if I'm in bad, not in very good shape here.
32	Cap Com	4:57	3. 5	Got 15 seconds, plenty of time, I'll give you a mark at 5:10 [elapsed time since launch].
	Bell 7	5:01.5	2. 5	OK, retro attitude [light] is still green.
	Cap Com	5:05	6	Retros on my mark, 3, 2, 1, mark.
	(1)			He's in limits. [Falls in the middle of last Cap Com communication.]

[1] Communicator unidentified.

Communication number	*Communicator*	*Time, min:sec*	*Transmission duration, sec*	*Communication*
33	Bell 7	5:11.5		OK, there's 1 firing, there's 1 firing.
	(1)	5:12	1	Retro 1. [Cuts out Bell 7.]
	Cap Com	5:13.5	1	Roger, retro 1.
34	Bell 7	5:19	2	There's 2 firing, nice little boost. There went 3.
	Cap Com	5:21	2. 5	Roger, 3, all retros are fired.
35	Bell 7	5:23.5	1	Roger, roger.
36	Bell 7	5:25.5	2. 5	OK, yeh, they're fired out right there.
	Cap Com	5:29	3	Roger, retrojettison armed.
37	Bell 7	5:33.5	2. 5	Retrojettison is armed, retrojettison is armed, going to rate command.
38	Bell 7	5:36	1. 5	OK, I'm going to switch.
	Cap Com	5:38	3	Roger. Understand manual fuel handle is in.
39	Bell 7	5:41	3	Manual fuel handle is in, mark, going to HF.
	Cap Com	5:44.5	1. 5	Roger, HF.
		5:52	6. 5	Liberty Bell 7, this is Cap Com on HF, 1, 2, 3, 4, 5. How do you read [Bell] 7?
	(1)			I got you.
40	Bell 7	6:08	18	. . . here, do you read me, do you read me on HF? . . . Going back to U [UHF] . . . [received by ATS ship]. Boy is that . . . Retro, I'm back on UHF and, ah, and the jett—the retros have jettisoned. Now I can see the Cape and, oh boy, that's some sight. I can't see too much.
	Cap Com	6:05	6	This is Cap Com on HF, 1, 2, 3, 4, 5. How do you read [Bell] 7?
41	Bell 7	6:34	3. 5	Roger, I am on UHF high, do you read me?
	Cap Com	6:38	4. 5	Roger, reading you loud and clear UHF high, can you confirm retrojettison?
42	Bell 7	6:41	3. 5	OK, periscope is retracting, going to reentry attitude.
	Cap Com	6:47	4. 5	Roger. Retros have jettisoned, scope has retracted, you're going to reentry attitude.
43	Bell 7	6:51.5	1	Affirmative.
	Cap Com	6:56.5	3. 5	Bell 7 from Cap Com, your IP [impact point] is right on.
44	Bell 7	7:00.5	3	Roger. I'm in reentry attitude.
45	Bell 7	7:05.5	0. 5	Ah.
	Cap Com	7:07	2. 5	Roger, how does it look out the window now?
46	Bell 7	7:09.5	4	Ah, the sun is coming in and so all I can see really is just, ah, just darkness, the sky is very black.
	Cap Com	7:14.5	3	Roger, you have some more time to look if you like.
	Cap Com	7:27	2. 5	[Bell] 7 from Cap Com, how do you feel up there?
47	Bell 7	7:30	3. 5	I feel very good, auto fuel is 90 [percent], manual is 50 [percent].
	Cap Com	7:33.5	3	Roger, 0.05g in 10 [seconds].
48	Bell 7	7:37	2	OK.
49	Bell 7	7:50.5	3	OK, everything is very good, ah.
	Bell 7	7:54	2. 5	I got 0.05g [light] and roll rate has started.
	Cap Com	7:57	1	Roger.
50	Bell 7	8:03.5	5	Got a pitch rate in here, OK, g's are starting to build.
	Cap Com	8:09	1. 5	Roger, reading you loud and clear.
51	Bell 7	8:11	5	Roger, g's are building, we're up to 6[g].
52	Bell 7	8:17	1. 5	There's 9[g].
53	Bell 7	8:19	11. 5	There's about 10[g]; the handle is out from under it; here I got a little pitch rate coming back down through 7[g].
	Cap Com	8:32	2	Roger, still sound good.
54	Bell 7	8:34.5	3	OK, the altimeter is active at 65 [thousand feet]. There's 60 [thousand feet].
	Cap Com	8:38.5	1. 5	Roger, 65,000.
55	Bell 7	8:42	7. 5	OK, I'm getting some contrails, evidently shock wave, 50,000 feet; I'm feeling good. I'm very good, everything is fine.
	Cap Com	8:49.5	2. 5	Roger, 50,000.

[1] Communicator unidentified.

Communication number	Communicator	Time, min:sec	Transmission duration, sec	Communication
56	Bell 7	8:52	1. 5	45,000, do you still read?
	Cap Com	8:54	2. 5	Affirmative. Still reading you. You sound good.
57	Bell 7	9:00.5	3	OK, 40,000 feet, do you read?
58	Bell 7	9:07	2	35,000 feet, if you read me.
59	Bell 7	9:19	7	30,000 feet, everything is good, everything is good.
	Cap Com	9:24	2. 5	Bell 7, this is Cap Com. How . . . . [Rest of communication not received.]
	(1)			Cape, do you read?
60	Bell 7	9:28	2	25,000 feet.
61	Bell 7	9:36.5	2. 5	Approaching drogue chute attitude.
62	Bell 7	9:41.5	4. 5	There's the drogue chute. The periscope has extended.
	Cap Com	9:45	4	This is . . . we have a green drogue [light] here, 7 how do you read?
63	Bell 7	9:49.5	13. 5	OK, we're coming down to 15,000 feet, if anyone reads. We're on emergency flow rate, can see out the periscope OK. The drogue chute is good.
	Cap Com			Roger, understand drogue is good, the periscope is out.
64	Bell 7	10:05.5	2	There's 13,000 feet.
	Cap Com			Roger.
65	Bell 7	10:14	25	There goes the main chute; it's reefed; main chute is good; main chute is good; rate of descent coming down, coming down to—there's 40 feet per second, 30 feet per, 32 feet per second on the main chute, and the landing bag is out green.
	(1)			Ah, it's better than it was, Chuck.
66	Bell 7	10:40.5	3	Hello, does anybody read Liberty Bell, main chute is good, landing bag [light] is on green.
	Cap Com			And the landing bag [light] is on green.
	ATS			Liberty Bell 7, Liberty Bell 7, this is Atlantic Ship Cap Com. Read you loud and clear. Our telemetry confirms your events. Over.
67	Bell 7			Ah, roger, is anyone reading Liberty Bell 7? Over.
	Card File 23			Roger, Liberty Bell 7, reading you loud and clear. This is Card File 23. Over.
68	Bell 7	10:52	4	Atlantic Ship Cap Com, this is Liberty Bell 7, how do you read me? Over.
	ATS			Read you loud and clear, loud and clear. Over. Liberty Bell 7, Liberty Bell 7, this is Atlantic Ship Cap Com. How do you read me? Over.
69	Bell 7	11:12	8	Atlantic Ship Cap Com, this is Liberty Bell 7, I read you loud and clear. How, me? Over.
	ATS			Roger, Bell 7, read you loud and clear, your status looks good, your systems look good. we confirm your events. Over.
70	Bell 7	11:28	4	Ah, roger, and confirm the fuel has dumped. Over.
	ATS			Roger, confirm again, confirm again, has your auto fuel dumped? Over.
71	Bell 7	11:42.5	2. 5	Auto fuel and manual fuel has dumped.
	ATS			Roger, roger.
72	Bell 7	11:47.5	3	And I'm in the process of putting the pins back in the door at this time.
73	Bell 7	12:04	5	OK, I'm passing down through 6,000 feet, everything is good, ah.
74	Bell 7	12:15	1. 5	I'm going to open my face plate.
75	Bell 7	12:35	16	Hello, I can't get one; I can't get one door pin back in. I've tried and tried and I can't get it back in. And I'm coming, ATS, I'm passing through 5,000 feet and I don't think I have one of the door pins in.
	ATS			Roger, Bell 7, roger.
76	Bell 7	13:04	2	Do you have any word from the recovery troops?
	Card File 23			Liberty Bell 7, this is Card File 23; we are heading directly toward you.

[1] Communicator unidentified.

Communication number	Communicator	Time, min:sec	Transmission duration, sec	Communication
77	Bell 7	13:18	4	ATS, this is Cap—this is Liberty Bell 7. Do you have any word from the recovery troops?
	ATS			Negative, Bell 7, negative. Do you have any transmission to MCC [Mercury Control Center]? Over.
78	Bell 7	13:33	13	Ah, roger, you might make a note that there is one small hole in my chute. It looks like it's about 6 inches by 6 inches—it's a sort of a—actually it's a triangular rip, I guess.
	ATS			Ah, roger, roger.
79	Bell 7	13:49	45	I'm passing through 3,000 feet, and all the fuses are in flight conditions; ASCS is normal, auto; we're on rate command; gyros are normal; auto retrojettison is armed; squibs are armed also. Four fuel handles are in; decompress and recompress are in; retro delay is normal; retroheat is off, cabin lights are both. TM [telemeter] is on. Rescue aids is auto; landing bag is auto; retract scope is auto; retroattitude is auto. All the three, five pull rings are in. Going down through some clouds to 2,000 feet. ATS, I'm at 2,000 feet; everything is normal.
	ATS			Roger, Bell 7, what is your rate of descent again? Over.
80	Bell 7	14:39	5	The rate of descent is varying between 28 and 30 feet per second.
	ATS			Ah, roger, roger, and once again verify your fuel has dumped. Over.
	(1)			Seven ahead at bearing 020. Over.
81	Bell 7	14:54	33	OK. My max g was about 10.2; altimeter is 1,000 [feet]; cabin pressure is coming toward 15 [psi].
	(1)			We'll make up.
	Bell 7			Temperature is 90 [°F].
	(1)			We'll make up an eye rep.
	Bell 7			Coolant quantity is 30 [percent]; temperature is 68 [°F]; pressure is 14 [psi]; main O_2 is 60 [percent]; normal is, main is 60 [percent]; emergency is 100 [percent]; suit fan is normal; cabin fan is normal. We have 21 amps, and I'm getting ready for impact here.
	Bell 7			Can see the water coming right on up.
	ATS			Liberty Bell 7, Liberty Bell 7, this is Atlantic Cap Com, do you read me? Over.
82	Bell 7		3	OK, does anyone read Liberty Bell 7? Over.
	Hunt Club 1			Liberty Bell 7, Hunt Club 1 is now 2 miles southwest you.
	Card File 9			Liberty Bell 7 this 9 Card File. We have your entry into the water. Will be over you in just about 30 seconds.
83	Bell 7	16:35	2	Roger, my condition is good; OK the capsule is floating, slowly coming vertical, have actuated the rescue aids. The reserve chute has jettisoned, in fact I can see it in the water, and the whip antenna should be up.
	(1)			Hunt Club, did you copy?
	(1)			OK, Hunt Club, this is . . . Don't forget the antenna.
	Hunt Club 1			This is Hunt Club, say again.
84	Bell 7	18:07	4	Hunt Club, this is Liberty Bell 7. My antenna should be up.
	Hunt Club 1			This is Hunt Club 1 . . . your antenna is erected.
85	Bell 7	18:16	1	Ah, roger.
	Bell 7	18:23	3	OK, give me how much longer it'll be before you get here.
	Hunt Club 1			This is Hunt Club 1, we are in orbit now at this time, around the capsule.
86	Bell 7	18:32.5	8. 5	Roger, give me about another 5 minutes here, to mark these switch positions here, before I give you a call to come in and hook on. Are you ready to come in and hook on anytime?
	Hunt Club 1			Hunt Club 1, roger we are ready anytime you are.

[1] Communicator unidentified.

Communication number	Communicator	Time, min:sec	Transmission duration, sec	Communication
87	Bell 7	18:44	5	OK, give me about another 3 or 4 minutes here to take these switch positions, then I'll be ready for you.
	Hunt Club 1			1, wilco.
	Card File 9			Hey Hunt Clubs, Card File, Card File 9, I'll stand by to escort you back as soon as you lift out. I keep other aircraft at at least 2,000 feet.
	Hunt Club 1			Ah, Bell 7 this is Hunt Club 1.
88	Bell 7	20:15	1.5	Go, go ahead Hunt Club 1.
	Hunt Club 1			Roger, this is 1, observe something, possibly the canister in the water along side capsule. Will we be interfering with any TM [telemetry] if we come down and take a look at it?
89	Bell 7	20:26	7.5	Negative, not at all, I'm just going to put the rest of this stuff on tape and then I'll be ready for you, in just about 2 more minutes, I would say.
	Hunt Club 1			1 roger.
	Cap Com			Liberty Bell 7, Cap Com at the Cape on a test count. Over.
	Cap Com			Liberty Bell 7, Cape Cap Com on a test count. Over.
	Card File 9			Any Hunt Club, this is 9 Card File.
	Hunt Club 1			Station calling Hunt Club, say again.
	Card File 9	24:03	22	This is Niner Cardfile, there's an object on a line in the water, ah, just about 160 degrees. The NASA people suspect it's the dye marker that didn't activate; ah, say it's about, ah, ¾ of a mile out from the capsule. Ah, after the lift out, will you take a check on it? Over.
	Hunt Club 1			Ah, this is Hunt Club 1, roger, will have Hunt Club 3 check at this time, you copy 3.
	Hunt Club 3			Hunt Club 1, believe he said ¾ of a mile?
	Card File 9			This is 9 Card, that is affirmative.
90	Bell 7	25:19.5	5.5	OK, Hunt Club. This is Liberty Bell 7. Are you ready for the pickup?
	Hunt Club 1			This is Hunt Club 1; this is affirmative.
91	Bell 7	25:30	5	OK, latch on, then give me a call and I'll power down and blow the hatch, OK?
	Hunt Club 1			This is Hunt Club 1, roger, will give you a call when we're ready for you to blow.
92	Bell 7	25:42	3	Roger, I've unplugged my suit so I'm kinda warm now so.
	Hunt Club 1			1, roger.
93	Bell 7	25:52.5	5	Now if you tell me to, ah, you're ready for me to blow, I'll have to take my helmet off, power down, and then blow the hatch.
	Hunt Club 1			1, roger, and when you blow the hatch, the collar will already be down there waiting for you, and we're turning base at this time.
94	Bell 7	26:09	1	Ah, roger.

No further communications were received as a result of the emergency egress required by the failure of the side hatch.

Reference

1. Slayton, Donald K.: *Pilot Training and Preflight Preparation.* Proc. Conf. on Results of the First U.S. Manned Suborbital Space Flight, NASA, Nat. Inst. Health, and Nat. Acad. Sci., June 6, 1961, pp. 53–60.

7. PILOT'S FLIGHT REPORT

By Virgil I. Grissom, *Astronaut, NASA Manned Spacecraft Center*

Introduction

The second Mercury manned flight was made on July 21, 1961. The flight plan provided a ballistic trajectory having a maximum altitude of 103 nautical miles, a range of 263 nautical miles, and a 5-minute period of weightlessness.

The following is a chronological report on the pilot's activities prior to, during, and after the flight.

Preflight

The preflight period is composed of two distinct areas. The first is the training that has been in progress for the past 2½ years and which is still in progress. The second area, and the one that assumes the most importance as launch date approaches, is the participation in the day-to-day engineering and testing that applies directly to the spacecraft that is to be flown.

Over the past 2 years, a great deal of information has been published about the astronaut training program and the program has been previously described in reference 1. In the present paper, I intend to comment on only three trainers which I feel have been of the greatest value in preparing me for this flight.

The first trainer that has proven most valuable is the Mercury procedures trainer which is a fixed-based computer-operated flight simulator. There are two of these trainers (fig. 7–1), one at the

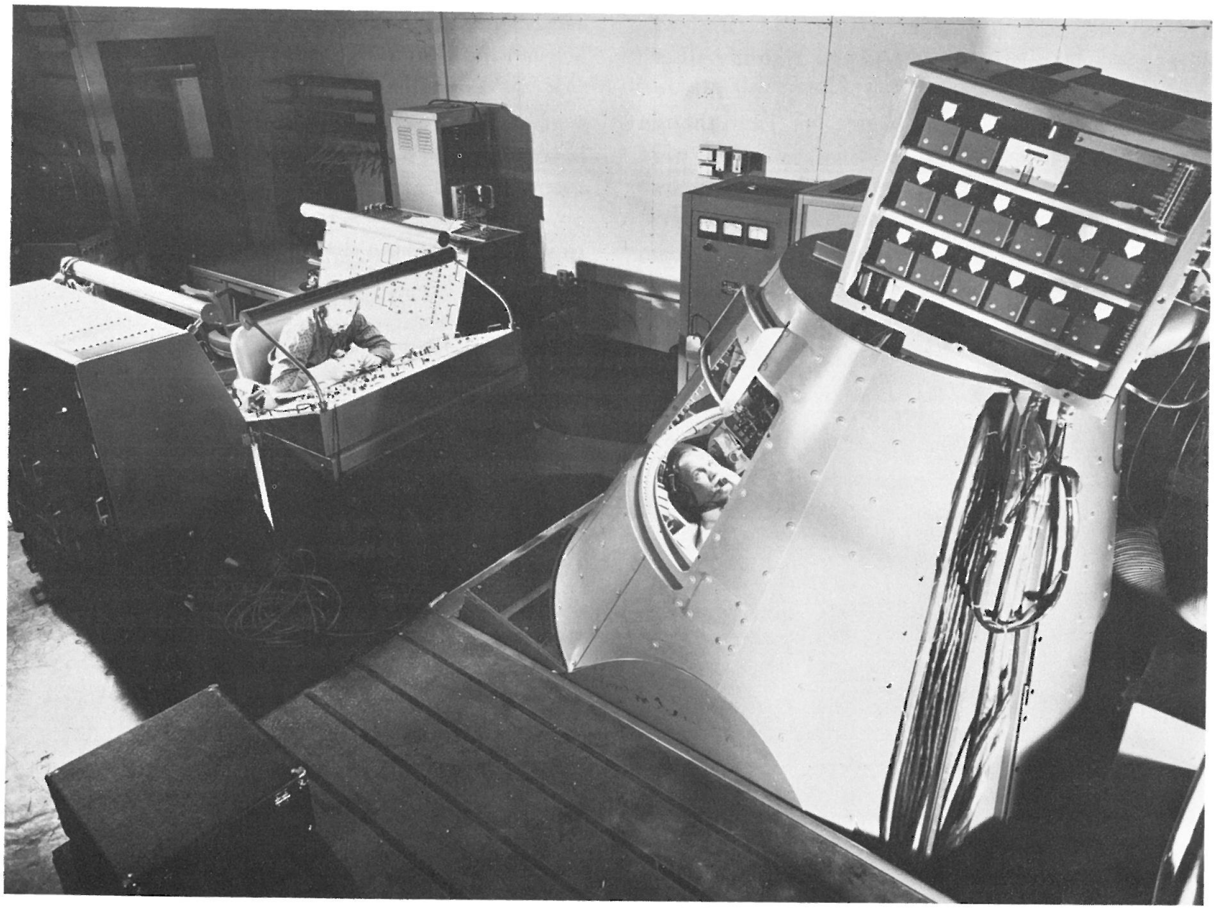

Figure 7–1. Procedures trainer.

NASA-Langley Air Force Base, Va., and one at the Mercury Control Center, Cape Canaveral, Fla. These procedures trainers have been used continuously throughout the program to learn the system operations, to learn emergency operating techniques during system malfunctions, to learn control techniques, and to develop operational procedures between pilot and ground personnel.

During the period preceding the launch, the trainers were used to finalize the flight plan and to gain a high degree of proficiency in flying the mission profile (fig. 7–2). First, the systems to be checked specifically by the pilot were determined. These were to be the manual proportional control system; the rate command control system; attitude control with instruments as a reference; attitude control with the earth-sky horizon as a reference; the UHF, HF, and emergency voice communications systems; and the manual retrofire override. The procedures trainer was then used to establish an orderly sequence of accomplishing these tasks. The pilot functions were tried and modified a great number of times before a satisfactory sequence was determined. After the flight plan was established, it was practiced until each phase and time was memorized. During this phase of training, there was a tendency to add more tasks to the mission flight plan as proficiency was gained. Even though the MR–4 flight plan (table 7–I) contained less pilot functions than the MR–3 flight plan, I found that the view out the window, which cannot be simulated, distracted me from the less important tasks and often caused me to fall behind the planned program. The only time this distraction concerned me was prior to retrofire; at other times, I felt that looking out the window was of greater importance than some of the planned menial tasks. In spite of this pleasant distraction, all tasks were accomplished with the exception of visual control of retrofire.

The second trainer that was of great value and one that I wish had been more readily available prior to launch was the air-lubricated free-attitude (ALFA) trainer at the NASA-Langley Air Force Base, Va. (fig. 7–3). This trainer provided the only training in visual control of the spacecraft. I had intended to use the earth-sky horizon as my primary means of attitude control and had spent a number of hours on the ALFA trainer practicing retrofire using the horizon as a reference. Because of the rush of events at Cape Canaveral during the 2 weeks prior to launch, I was unable to use this trainer. I felt this probably had some bearing on my instinctive switch to instruments for retrofire during the flight, instead of using the horizon as a reference.

The third training device that was of great value was the Johnsville human centrifuge. With this device, we learned to control the spacecraft during the accelerations imposed by launch and reentry and learned muscle control to aid blood circulation and respiration in the acceleration environment. The acceleration buildup during the flight was considerably smoother than that experienced on the centrifuge and probably for this reason and for obvious psychological reasons, the g-forces were much easier to withstand during the flight than during the training missions.

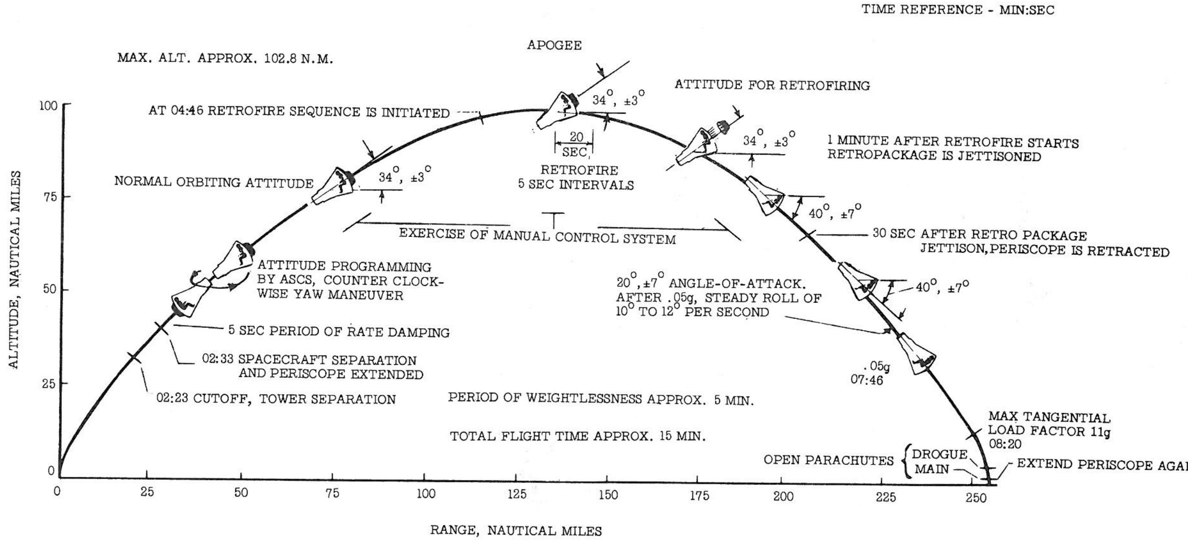

FIGURE 7–2. Mission profile.

FIGURE 7-3. ALFA trainer.

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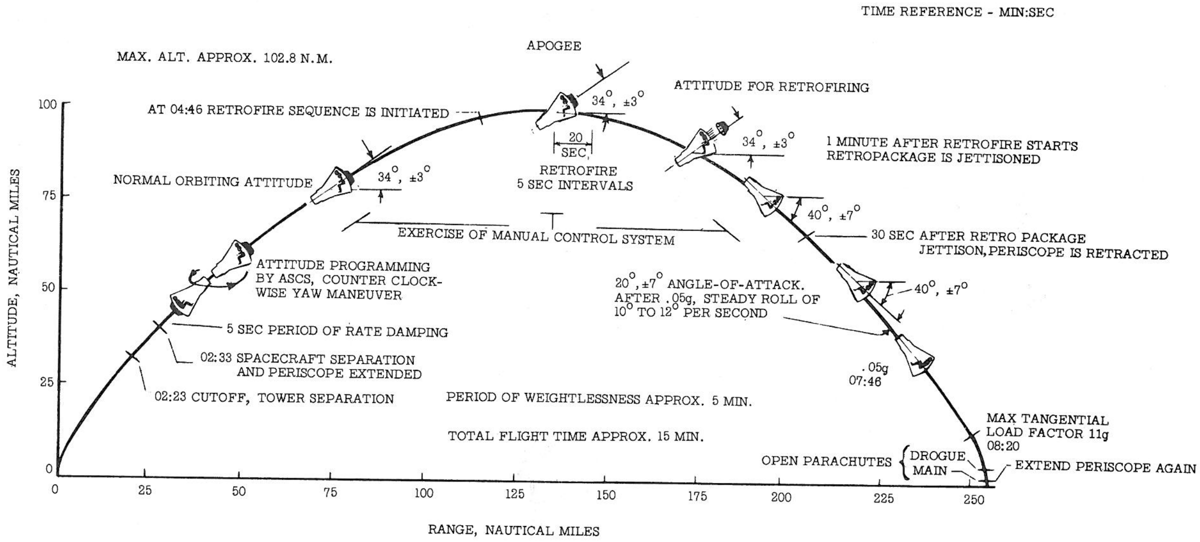

FIGURE 7–2. Mission profile.

FIGURE 7–3. ALFA trainer.

One other phenomenon that was experienced on the centrifuge proved to be of great value during the flight. Quite often, as the centrifuge changed rapidly from a high g-level to a low or 1 g level, a false tumbling sensation was encountered. This became a common and expected sensation and when the same thing occurred at launch vehicle cutoff, it was in no way disturbing. A quick glance at my instruments convinced me that I, indeed, was not tumbling.

The pilot's confidence comes from all of the foregoing training methods and from many other areas, but the real confidence comes from participation in the day-to-day engineering decisions and testing that occur during the preflight checkout at Cape Canaveral. It was during this time that I learned the particular idiosyncrasies of the spacecraft that I was to fly. A great deal of time had already been spent in learning both normal and emergency system operations. But during the testing at the preflight complex and at the launching pad, I learned all the differences between this spacecraft and the simulator that had been used for training. I learned the various noises and vibrations that are connected with the operation of the systems. This was the time that I really began to feel at home in this cockpit. This training was very beneficial on launch day because I felt that I knew this spacecraft and what it would do, and having spent so much time in the cockpit I felt it was normal to be there.

As a group, we astronauts feel that after the spacecraft arrives at the Cape, our time is best spent in participating in spacecraft activities. This causes some conflict in training, since predicting the time test runs of the preflight checkouts will start or end is a mystic art that is understood by few and is unreliable at its best. Quite frequently this causes training sessions to be canceled or delayed, but it should be of no great concern since most of the training has been accomplished prior to this time. The use of the trainers during this period is primarily to keep performance at a peak and the time required will vary from pilot to pilot.

At the time the spacecraft is moved from the preflight complex to the launching pad, practically all training stops. From this time on, I was at the pad full time participating in or observing every test that was made on the spacecraft—launch-vehicle combination. Here, I became familiar with the launch procedure and grew to know and respect the launch crew. I gained confidence in their professional approach to and execution of the prelaunch tests.

The Flight

On the day of the flight, I followed the following schedule:

Event	a.m. e.s.t.
Awakened	1:10
Breakfast	1:25
Physical examination	1:55
Sensors attached	2:25
Suited up	2:35
Suit pressure check	3:05
Entered transfer van	3:30
Arrived at pad	3:55
Manned the spacecraft	3:58
Launched	7:20

As can be seen, 6 hours and 10 minutes elapsed from the time I was awakened until launch. This time is approximately evenly divided between activities prior to my reaching the pad and time I spent at the pad. In this case, we were planning on a launch at 6:00 a.m. e.s.t., but it will probably always be normal to expect some holds that cannot be predicted. While this time element appears to be excessive, we can find no way to reduce it below this minimum at the present. Efforts are still continuing to reduce the precountdown time so that the pilot will not have had an almost full working day prior to lift-off.

After insertion in the spacecraft, the launch countdown proceeded smoothly and on schedule until T−45 minutes when a hold was called to install a misalined bolt in the egress hatch.

After a hold of 30 minutes, the countdown was resumed and proceeded to T−30 minutes when a brief hold was called to turn off the pad searchlights. By this time, it was daylight; and the lights, which cause interference with launch-vehicle telemetry, were no longer needed.

One more hold was called at T−15 minutes to await better cloud conditions because the long focal length cameras would not have been able to obtain proper coverage through the existing overcast.

After holding for 41 minutes, the count was resumed and proceeded smoothly to lift-off at 7:20 a.m., e.s.t.

The communications and flow of information prior to lift-off were very good. After participating in the prelaunch test and the cancellation 2 days previously, I was very familiar with the countdown and knew exactly what was going on at all times.

As the Blockhouse Capsule Communicator (Cap Com) called ignition, I felt the launch vehicle start to vibrate and could hear the engines start. Just seconds after this, the elapsed-time clock started and the Mercury Control Center Cap Com confirmed lift-off. At that time, I punched the Time Zero Override, started the stopwatch function on the spacecraft clock, and reported that the elapsed-time clock had started.

The powered flight portion of the mission was in general very smooth. A low-order vibration started at approximately T+50 seconds, but it did not develop above a low level and was undetectable after about T+70 seconds. This vibration was in no way disturbing and it did not cause interference in either communications or vision. The magnitude of the accelerations corresponds well to the launch simulations on the centrifuge, but the onset was much smoother.

Communications throughout the powered flight were satisfactory. The VOX (voice operated relay) was used for pilot transmissions instead of the push-to-talk button. The noise level was never high enough at any time to key the transmitter. Each standard report was made on time and there was never any requirement for myself or the Cap Com to repeat any transmission.

Vision out the window was good at all times during launch. As viewed from the pad, the sky was its normal light blue; but as the altitude increased, the sky became a darker and darker blue until approximately 2 minutes after lift-off, which corresponds to an altitude of approximately 100,000 feet, the sky rapidly changed to an absolute black. At this time, I saw what appeared to be one rather faint star in the center of the window (fig. 7–4). It was about equal in brightness to Polaris. Later, it was determined that this was the planet Venus whose brightness is equal to a star of magnitude of −3.

Launch-vehicle engine cutoff was sudden and I could not sense any tail-off of the launch vehicle. I did feel, as I described earlier, a very brief tumbling sensation. The firing of the escape-tower clamp ring and escape rocket is quite audible and I could see the escape rocket motor and tower throughout its tail-off burning phase and for what seemed like quite some time after that climbing off to my right. Actually, I think I was still watching the tower at the time the posigrade rockets fired, which occured 10 seconds after cutoff. The tower was still definable as a long, slender object against the black sky at this time.

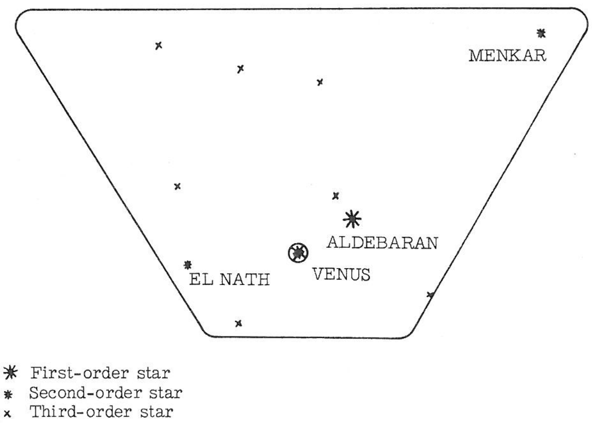

FIGURE 7–4. Approximate view of stars through centerline window.

The posigrade firing is a very audible bang and a definite kick, producing a deceleration of approximately 1g. Prior to this time, the spacecraft was quite stable with no apparent motion. As the posigrade rockets separated the spacecraft from the launch vehicle, the spacecraft angular motions and angular accelerations were quite apparent. Spacecraft damping which was to begin immediately after separation was apparently satisfactory, although I cannot really report on the magnitude of any angular rates caused by posigrade firing.

The spacecraft turnaround to retrofire attitude is quite a weird maneuver to ride through. At first, I thought the spacecraft might be tumbling out of control. A quick check of the instruments indicated that turnaround was proceeding much as those experienced on the procedures trainer, with the expection of roll attitude which appeared to be very slow and behind the schedule that I was expecting.

As the turnaround started, I could see a bright shaft of light, similar to the sun shining into a blackened room, start to move from my lower left up across my torso. Even though I knew the window reduces light transmissions equivalent to the earth's atmosphere, I was concerned that it might shine directly into my eyes and blind me. The light moved across my torso and disappeared completely.

A quick look through the periscope after it extended did not provide me with any useful information. I was unable to see land, only clouds and the ocean.

The view through the window became quite spectacular as the horizon came into view. The sight was truly breathtaking. The earth was very bright, the sky was black, and the curvature of the earth was quite prominent. Between the earth and sky, there was a border which started at the earth as a light blue and became increasingly darker with altitude. There was a transition region between the dark blue and the black sky that is best described as a fuzzy gray area. This is a very narrow band, but there is no sharp transition from blue to black. The whole border appeared to be uniform in height over the approximately 1,000 miles of horizon that was visible to me.

The earth itself was very bright. The only landmark I was able to identify during the first portion of the weightlessness period was the Gulf of Mexico coastline between Apalachicola, Fla., and Mobile, Ala. (fig. 7–5). The cloud coverage was quite extensive and the curvature of this portion of the coast was very difficult to distinguish. The water and land masses were both a hazy blue, with the land being somewhat darker. There was a frontal system south of this area that was clearly defined.

FIGURE 7–5. Approximate view of earth through centerline window.

One other section of the Florida coast came into view during the left yaw maneuver, but it was a small section of beach with no identifiable landmarks.

The spacecraft automatic stabilization and control system (ASCS) had made the turnaround maneuver from the position on the launch vehicle to retrofire attitude. The pitch and yaw axes stabilized with only a moderate amount of overshoot as predicted, but the roll attitude was still being programed and was off by approximately 15° when I switched from the autopilot to the manual proportional control system. The switchover occurred 10 seconds later than planned to give the ASCS more time to stabilize the spacecraft. At this point, I realized I would have to hurry my programed pitch, yaw, and roll maneuvers. I tried to hurry the pitch-up maneuver; I controlled the roll attitude back within limits, but the view out the window had distracted me, resulting in an overshoot in pitch. This put me behind in my schedule even more. I hit the planned yaw rate but overshot in yaw attitude again. I realized that my time for control maneuvers was up and I decided at this point to skip the planned roll maneuver, since the roll axis had been exercised during the two previous maneuvers, and go immediately to the next task.

This was the part of the flight to which I had been looking forward. There was a full minute that was programed for observing the earth. My observations during this period have already been reported in this paper, but the control task was quite easy when only the horizon was used as a reference. The task was somewhat complicated during this phase, as a result of lack of yaw reference. This lack was not a problem after retrofire when Cape Canaveral came into view. I do not believe yaw attitude will be a problem in orbital flight because there should be ample time to pick adequate checkpoints; even breaks in cloud formations would be sufficient.

The retrosequence started automatically and at the time it started, I was slightly behind schedule. At this point, I was working quite hard to get into a good retrofire attitude so that I could fire the retrorockets manually. I received the countdown to fire from Mercury Control Center Cap Com and fired the retrorockets manually. The retrorockets, like the escape rocket and posigrades, could be heard quite clearly. The thrust buildup was rapid and smooth. As the first retrorocket fired, I was looking out the window and could see that a definite

yaw to the right was starting. I had planned to control the spacecraft attitude during retrofire by using the horizon as a reference; but as soon as the right yaw started, I switched my reference to the flight instruments. I had been using instruments during my retrofire practice for the 2 weeks prior to the launch in the Cape Canaveral procedures trainer since the activity at the Cape prevented the use of the ALFA trainer located at the NASA-Langley Air Force Base, Va. This probably explains the instinctive switch to the flight instruments.

The retrofire difficulty was about equal to the more severe cases that have been presented on the procedures trainer.

Immediately after retrofire, Cape Canaveral came into view. It was quite easy to identify. The Banana and Indian Rivers were easy to distinguish and the white beach all along the coast was quite prominent. The colors that were the most prominent were the blue of the ocean, the brownish-green of the interior, and the white in between, which was obviously the beach and surf. I could see the building area on Cape Canaveral. I do not recall being able to distinguish individual buildings, but it was obvious that it was an area where buildings and structures had been erected.

Immediately after retrofire, the retrojettison switch was placed in the armed position, and the control mode was switched to the rate command control system. I made a rapid check to ascertain that the system was working in all axes and then I switched from the UHF transmitter to the HF transmitter.

This one attempt to communicate on HF was unsuccessful. At approximately peak altitude, the HF transmitter was turned on and the UHF transmitter was turned off. All three receivers—UHF, HF, and emergency voice—were on continuously. Immediately after I reported switching to HF, the Mercury Control Center started transmitting to me on HF only. I did not receive any transmission during this period. After allowing the HF transmitter approximately 10 seconds to warm up, I transmitted but received no acknowledgement that I was being received. Actually, the Atlantic Ship telemetry vessel located in the landing area and the Grand Bahama Island did receive my HF transmissions. Prior to the flight, both stations had been instructed not to transmit on the assigned frequencies unless they were called by the pilot. After switching back to the UHF transmitter, I received a call on the emergency voice that was loud and clear. UHF communications were satisfactory throughout the flight. I was in continuous contact with some facility at all times, with the exception of a brief period on HF.

Even though all communications equipment operated properly, I felt that I was hurrying all transmissions too much. All of the sights, sounds, and events were of such importance that I felt compelled to talk of everything at once. It was a difficult choice to decide what was the most important to report at any one time. I wanted as much as possible recorded so that I would not have to rely on my memory so much for later reporting.

As previously mentioned, the control mode was switched from manual proportional to rate command immediately after retrofire. The procedures trainer simulation in this system seems to be slightly more difficult than the actual case. I found attitudes were easy to maintain and rates were no problem. The rate command system was much easier to fly than the manual proportional system. The reverse is normally true on the trainer. The sluggish roll system was probably complicating the control task during the manual proportional control phase of the flight, while roll accelerations appeared to be normal on the rate command system.

The rate command control system was used after retrofire and throughout the reentry phase of the flight. At the zero rate command position, the stick was centered. This system had a deadband of ± 3 deg/sec. Our experience on the procedures trainer had indicated that this system was more difficult to fly than the manual proportional control system. This was not the case during this flight. Zero rates and flight attitudes were easy to maintain. The records do indicate that an excessive amount of fuel was expended during this period. Approximately 15 percent of the manual fuel supply was used during the 2 minutes the system was operating. A major portion of the 2-minute period was during the reentry when thrusters were operating almost continuously to dampen the reentry oscillations.

The 0.05g telelight illuminated on schedule and shortly thereafter I reported g's starting to build. I checked the accelerometer and the g-level was something less than 1g at this time. The next time I reported, I was at 6g and I continued to report and function throughout the high-g portion of the flight.

The spacecraft rates increased during the reentry, indicating that the spacecraft was oscillating in both yaw and pitch. I made a few control inputs at this time, but I could not see any effects on the rates, so I decided just to ride out the oscillations. The pitch

rate needle was oscillating full scale at a rapid rate of ± 6 deg/sec during this time and the yaw rate began oscillating full scale slightly later than pitch. At no time were these oscillations noticeable inside the spacecraft.

During this phase of reentry and until main parachute deployment, there is a noticeable roar and a mild buffeting of the spacecraft. This is probably the noise of a blunt object moving rapidly through the atmosphere and the buffeting is not distracting nor does it interfere with pilot function.

The drogue parachute deployment is quite visible from inside the spacecraft and the firing of drogue parachute mortar is clearly audible. The opening shock of the drogue parachute is mild; there is a mild pulsation or breathing of the drogue parachute which can be felt inside the spacecraft.

As the drogue parachute is released, the spacecraft starts to drop at a greater rate. The change in g-field is quite noticeable. Main parachute deployment is visible out the window also. A mild shock is felt as the main parachute deploys in its reefed condition. The complete parachute is visible at this time. As the reefing cutters fire, the parachute deploys to its fully opened condition. Again, a mild shock is felt. About 80 percent of the parachute is visible at this time and it is quite a comforting sight. The spacecraft rotates and swings slowly under the parachute at first; the rates are mild and hardly noticeable.

The spacecraft landing in the water was a mild jolt; not hard enough to cause discomfort or disorientation. The spacecraft recovery section went under the water and I had the feeling that I was on my left side and slightly head down. The window was covered completely with water and there was a disconcerting gurgling noise. A quick check showed no water entering the spacecraft. The spacecraft started to slowly right itself; as soon as I was sure the recovery section was out of the water, I ejected the reserve parachute by actuating the recovey aids switch. The spacecraft then righted itself rapidly.

I felt that I was in good condition at this point and started to prepare myself for egress. I had previously opened the face plate and had disconnected the visor seal hose while descending on the main parachute. The next moves in order were to disconnect the oxygen outlet hose at the helmet, unfasten the helmet from the suit, release the chest

(a) Normal stored position.

(b) Unrolled position.

Figure 7–6. Neck dam.

strap, release the lap belt and shoulder harness, release the knee straps, disconnect the biomedical sensors, and roll up the neck dam. The neck dam is a rubber diaphragm that is fastened on the exterior of the suit, below the helmet attaching ring. After the helmet is disconnected, the neck dam is rolled around the ring and up around the neck, similar to a turtle-neck sweater. (See fig. 7–6.) This left me connected to the spacecraft at two points, the oxygen inlet hose which I needed for cooling and the helmet communications lead.

At this time, I turned my attention to the door. First, I released the restraining wires at both ends and tossed them towards my feet. Then I removed the knife from the door and placed it in the survival pack. The next task was to remove the cover and safety pin from the hatch detonator. I felt at this time that everything had gone nearly perfectly and that I would go ahead and mark the switch position chart as had been requested.

After about 3 or 4 minutes, I instructed the helicopter to come on in and hook onto the spacecraft and confirmed the egress procedures with him. I unhooked my oxygen inlet hose and was lying on the couch, waiting for the helicopter's call to blow the hatch. I was lying flat on my back at this time and I had turned my attention to the knife in the survival pack, wondering if there might be some way I could carry it out with me as a souvenir. I heard the hatch blow—the noise was a dull thud—and looked up to see blue sky out the hatch and water start to spill over the doorsill. Just a few minutes before, I had gone over egress procedures in my mind and I reacted instinctively. I lifted the helmet from my head and dropped it, reached for the right side of the instrument panel, and pulled myself through the hatch.

After I was in the water and away from the spacecraft, I noticed a line from the dyemarker can over my shoulder. The spacecraft was obviously sinking and I was concerned that I might be pulled down with it. I freed myself from the line and noticed that I was floating with my shoulders above water.

The helicopter (fig. 7–7) was on top of the spacecraft at this time with all three of its landing gear in the water. I thought the copilot was having difficulty hooking onto the spacecraft and I swam the 4 or 5 feet to give him some help. Actually, he had cut the antennae and hooked the spacecraft in record time.

The helicopter pulled up and away from me with the spacecraft and I saw the personal sling start down; then the sling was pulled back into the helicopter and it started to move away from me. At this time, I knew that a second helicopter had been assigned to pick me up, so I started to swim away from the primary helicopter. I apparently got caught in the rotorwash between the two helicopters because I could not get close to the second helicopter, even though I could see the copilot in the door with a horsecollar swinging in the water. I finally reached the horsecollar and by this time, I was getting quite exhausted. When I first got into the water, I was floating quite high up; I would say my armpits were just about at the water level. But the neck dam was not up tight and I had forgotten to lock the oxygen inlet port; so the air was gradually seeping out of my suit. Probably the most air was going out around the neck dam, but I could see that I was gradually sinking lower and lower in the water and was having a difficult time staying afloat. Before the copilot finally got the horsecollar to me, I was going under water quite often. The mild swells we were having were breaking over my head and I was swallowing some salt water. As I reached the horsecollar, I slipped into it and I knew that I had it on backwards (fig. 7–8); but I gave the "up" signal and held on because I knew that I wasn't likely to slip out of the sling. As soon as I got into the helicopter, my first thought was to get on a life preserver so that if anything happened to the helicopter, I wouldn't have another ordeal in the water. Shortly after this time, the copilot informed me that the spacecraft had been dropped as a result of an engine malfunction in the primary helicopter.

Postflight

The postflight medical examination onboard the carrier was brief and without incident. The loss of the spacecraft was a great blow to me, but I felt that I had completed the flight and recovery with no ill effects.

The postflight medical debriefing at the Grand Bahama Island installation was thorough and complete. The demands on me were not unreasonable.

Conclusions

From the pilot's point of view the conclusions reached from the second U.S. manned suborbital flight are as follows:

(1) The manual proportional control system functioned adequately on this flight. The system is capable of controlling the retrofire accurately and

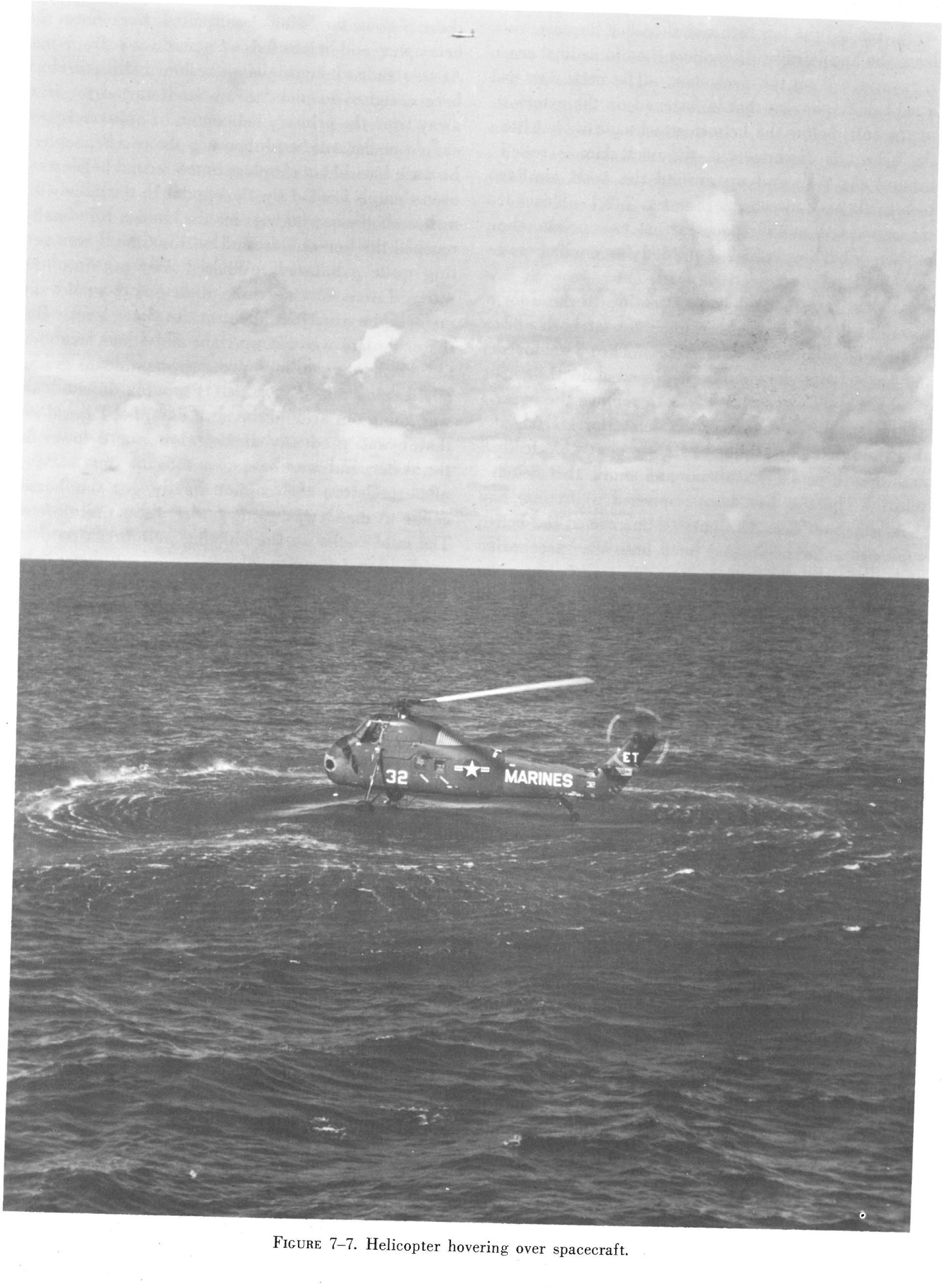

FIGURE 7–7. Helicopter hovering over spacecraft.

safely. The roll axis is underpowered and causes some difficulty. The rate command system functioned very well during this flight. All rates were damped satisfactorily, and it is easy to hold and maintain the attitudes with the rate command system. If the rate of fuel consumption that was experienced on this flight is true in all cases, it would not be advisable to use the rate command system during ordinary orbital flight to control attitudes. It should be used only for retrofire and reentry. The autopilot functioned properly with the possible exception of the 5 seconds of damping immediately after separation. This period is so brief that it was impossible to determine the extent of any damping. The turnaround maneuver in the pitch and yaw axes was approximately as predicted, but the roll axis was slow to respond.

(2) The pilot's best friend on the orbital flight is going to be the window. Out this window, I feel he will be able to ascertain accurately his position at all times. I am sure he will be able to see stars on the dark side and possibly on the daylight side, with a little time to adapt the eyes. The brighter stars and planets will certainly be visible.

(3) Spacecraft rates and oscillations are very easy to ascertain by looking at the horizon and ground checkpoints. I feel that drift rates will be easy to distinguish on an orbital flight when there is time to concentrate on specific points outside the window.

(4) Sounds of pyrotechnics, control nozzles, and control solenoids are one of the pilot's best cues as to what is going on in the spacecraft and in the sequencing. The sounds of posigrades, retrorockets, and mortar firing are so prominent that these become the primary cues that the event has occurred. The spacecraft telelight panel becomes of secondary importance and merely confirms that a sequence has happened on time. The sequence panel's main value is telling the pilot when an event should have occurred and has not.

(5) Vibrations throughout the flight were of a low order and were not disturbing. The buffeting at maximum dynamic pressure and a Mach number of 1 on launch was mild and did not interfere with

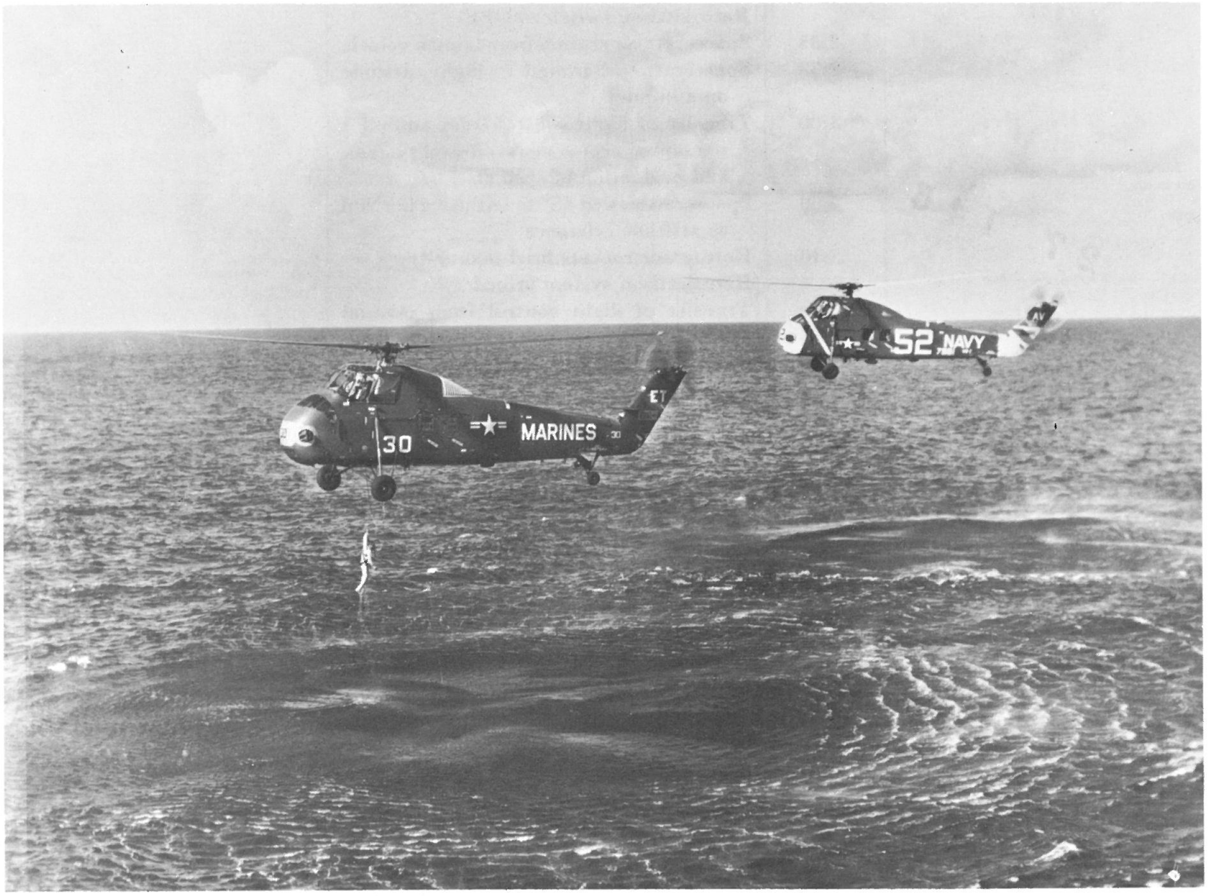

FIGURE 7–8. Helicopter recovering pilot (horsecollar on backwards).

pilot functions. Communications and vision were satisfactory throughout this period. The mild buffeting on reentry does not interfere with any pilot functions.

(6) Communications throughout the flight were satisfactory. Contact was maintained with some facility at all times. There was never any requirement to repeat a transmission.

(7) During the flight, all spacecraft systems appeared to function properly. There was no requirement to override any system. Every event occurred on time and as planned.

Reference

1. Slayton, Donald K.: *Pilot Training and Preflight Preparation.* Proc. Conf. on Results of the First U.S. Manned Suborbital Space Flight, NASA, Nat. Inst. Health, and Nat. Acad. Sci., June 6, 1961, pp. 53–60.

Table 7–I.—*Flight Plan*

Time, min:sec	Event
0:00	Lift-off
0:30	Systems report
1:00	Systems report
1:15	Cabin pressure report
1:30	Systems report
2:00	Systems report
2:23	Launch-vehicle engine cutoff Tower jettison Retrojettison switch to OFF
2:33	Spacecraft separation from launch vehicle
2:38	Spacecraft turnaround to flight attitude on autopilot
3:00	Transfer of flight control from autopilot to manual proportional control system, and evaluation of system
4:00	Spacecraft yawed 45° to left using horizon as attitude reference
5:10	Retrograde rockets fired manually
5:35	Retrojettison system armed Transfer of flight control from manual proportional control system to rate command control system Radio transmitter switched from UHF to HF
6:10	Retropackage jettison
6:40	Periscope retracts automatically Spacecraft positioned into reentry attitude
7:00	Communications switched back to UHF transmitter
7:46	Reentry starts
9:41	Drogue parachute deploys Snorkels open Emergency rate oxygen flow
10:13	Main parachute deployment
15:37	Landing

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